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ABSTRACT

This training manual, the first of two volumes, comprises the first six blocks in a nine-block in-service training course for apprentices working in heavy duty mechanics. Addressed in the individual blocks included in this volume are the following topics: shop equipment and practices; procedures for starting, moving, and stopping equipment; the principles and theory of hydraulics; brakes; power trains; and frames, suspensions, running gear, and working attachments (bearings and seals; track machine undercarriages; track machine final drives; track machine steering; wheel machine suspensions; tires, rims, and wheels; wheel machine final drives; wheel machine steering and front suspension; and working attachments). Each block contains a section on parts theory that gives the purpose, topics, operations, and applications of the parts and systems being discussed; a set of questions on parts theory; a section on scheduled maintenance and service repair; a set of questions on service; and a list of validated tasks to be completed during the course of daily on-the-job routines. The manual is illustrated with photographs and drawings. (MN)

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Heavy Duty Mechanics Apprenticeship Training, Module One

VOLUME I

Province of British Columbia

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This manual was prepared for publication by:
Leslie A. Batchelor,
Heavy Duty Mechanics Instructor,
Cariboo College.
Richard Abercrombie, Editor.

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INTRODUCTION

This is an in-service training manual for apprentices working in heavy duty mechanics shops who wish to complete **Module One, Heavy Duty Mechanics Apprenticeship Training** in-service. It covers the same material that is taught in the 14 week training program for Module One at the vocational schools. Although you don't have an instructor to assist you like apprentices at school, you will receive assistance from your employer and the journeyman you work with.

The manual is divided into nine blocks: (1) Shop Equipment and Practices, (2) Starting, Stopping, Moving Equipment, (3) Hydraulics, (4) Brakes, (5) Power Trains, (6) Frames, Suspension, Running Gear and Working Attachments, (7) Engines, (8) Electricity, and (9) Winches, Hoists and Cables. The material in blocks 1, 2, 6 and 9 is dealt with in a fairly thorough manner as these subjects won't be covered again in your training courses. The other blocks, blocks 3, 4, 5, 7 and 8, are introductions that give a basic grounding in their subjects. The topics in these blocks will be covered in greater detail in later courses. The main idea behind the depth that subjects are studied in this manual is to try to relate course material to the work you will actually be doing in the shop at this level of your apprenticeship. This is the reason, for example, that detailed information is given on frames, suspensions and running gear, whereas only basic information is given on electricity: it is assumed that you will be doing a lot of work on suspension and running gear, but little on electrical systems.

Each of the blocks is laid out in the following pattern: the block begins with a section on parts theory that gives the purpose, types, operations (how they work) and applications (where they are used) of the parts and systems being discussed. A set of questions follows the parts theory, the answers to which are given at the end of the block. Next is a section on service that is divided into Daily Routine Maintenance, Scheduled Maintenance and Service Repair. Daily Routine Maintenance deals with watchful visual checks and adjustments; Scheduled Maintenance with scheduled lubrication and checks; Service Repair with removal, disassembly, repair or replacement and installations. The Service Repair sections in the blocks that are written at a basic level are limited to the types of repair that you are likely to be doing in your shop. Another set of questions follows the service section. The blocks end with a list of practical tasks that should be done during daily work at your job. Your employer has a Task Check Chart, that he will complete to vouch that you have done all the tasks listed in the manual.

Following is some advice on how to approach the course:

- It is expected that the program will be completed within a three month period; however, provision is made for up to a three month extension if required. Try to space the blocks out over the time you set to do the course. There is a lot of material here, and if you leave it all to the end, you won't get finished. Monitoring of your progress in the course is done by your employer and by contact with the Apprenticeship Branch. Since this is an individualized learning package, there is no one standing over you telling you to do so much today and so much tomorrow. The onus is on you to keep a regular progress through the course. And it won't be easy.
- Don't skip out a section thinking that you already know it. There probably will be material in it that you are uncertain of. And besides, if you know most of the material already you'll be able to go through it quickly.
- Blocks 1, 2, 3, 4 and 5 should be done first. The other blocks can be taken in any order, although it's probably best to take them in the order in which they come.
- The questions are straightforward; there are no trick ones. They can all be answered from a close study of the text. Try to do as many of the questions as you can, without going back to the text. If you can't get a question, then open the text and seek the answer rather than turning to the answers. This way you re-read the topic and get a more complete understanding of it than if you just look up the answer.
- The practical tasks should normally be completed as you work on the material in each block; however, this may not be

practical due to other work commitments in the shop.

N.B. Some tasks may have already been covered in your day to day work.

Check with your employer to ensure that all areas of practical training have been covered.

— When you complete this manual and the practical tasks you will be required to write an Apprenticeship Branch examination.

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BLOCK

1

Shop Equipment and Practices

THE HEAVY DUTY MECHANICS TRADE

A heavy duty mechanic apprentice learns how to maintain and repair such heavy duty machines as tractors, dozers, loaders, graders, cranes, shovels and trucks. The work ranges from simple daily maintenance checks to complex rebuilding of major components. A good mechanic has a basic knowledge of mechanics that he/she can apply when confronted with a problem, knows how to use service manuals, tools and equipment to best advantage, and is resourceful when the need arises.

There are many opportunities for qualified heavy duty mechanics. Some of the areas they can work in are: light and heavy duty construction, trucking, mining, logging, farming, public utilities, the marine industry, and manufacturing. Heavy duty mechanics may work on a number of different types of machines or they may specialize on one. Also, they may specialize further by doing only one type of repair, e.g., transmission work. There is room for advancement in the trade if mechanics are so inclined; they can become charge hands, foremen, superintendents or service managers. Becoming an instructor in schools or for companies is another opportunity for experienced mechanics.

UNION JURISDICTION

Some jobs require the skills of several trades at once; for example a job may need a welder, electrician, mechanic, millwright, operator, pipefitter. To protect jobs in their individual trades, unions have jurisdiction over their parts of the job. Crossing a trade line, e.g., welding when a welder should be called in, can cause a lot of hard feelings. Most likely trade jurisdiction will be clearly explained to you by your supervisor or union representative. Follow jurisdiction rules. Remember, it works both ways: you protect the jobs in other trades, and they in turn protect yours.

SERVICE LITERATURE, PARTS LISTS, AND REPORTS

Service Manuals

With today's sophisticated equipment, service manuals are very important tools for mechanics. The manuals usually give a description of the part and its operation, then give step by step procedures for daily, routine maintenance and scheduled maintenance, for removal and installation of components, and for disassembly, repair and assembly. Tools needed for the work are generally indicated. Many manuals also give procedures to diagnose and troubleshoot malfunctions. Some people think that opening a service manual is a sign of weakness showing a lack of knowledge. Nothing could be further from the truth. Smart mechanics, except when they are doing a job they are very familiar with, always have the service manual nearby.

Most manufacturers issue service manuals for their equipment. Besides these, several companies publish general service manuals that contain information on many different types of components and machines. Although these general manuals can be helpful, the manufacturer's manual is usually best. Remember, however, that as much information as service manuals contain, they are not textbooks. They do not give you the general theory that lies behind a part or component's design, operation, or servicing. Nor do they compare similar types of components or parts used by other manufacturers.

Manufacturers use different formats in their manuals. Before you use a specific service manual, it is important to understand how its information is organized. If you are not familiar with a manual, read the introductory section that explains how to use it. An example from an introduction in a service manual for a General Motor's truck is given below.

IMPORTANT — READ THIS PAGE

MODELS COVERED

This manual contains "On-The-Vehicle" maintenance and light repair information on Series 70 through 9502 except M,N 9003-9502. Since truck models with various combinations of equipment are covered in this manual, the reader must necessarily refer to truck model applications and methods of distinguishing design differences in each manual section.

All standard equipment and the most commonly used regular production options are included in this manual. Many special equipment and accessory items are available on these trucks, however, these items are too numerous to permit their coverage in this manual.

MANUAL ARRANGEMENT

This manual is divided into major sections and sub-sections in the sequence shown on the margin of the title page. A black tab bearing the major section number is placed on the first page of each major section which indexes with the tab on the title page. A section contents is also included on the first page of each major section, when the major section is divided into sub-sections.

PAGE AND ILLUSTRATION NUMBERS

The manual pages are numbered consecutively within each section and sub-section. Illustrations are numbered consecutively within each section, or within each sub-section when the major section is so divided.

METRIC CONVERSIONS

In the event metric conversions are required, refer to conversion tables at the back of this manual.

SPECIFICATIONS

Service data, fits, and tolerances are listed at the end of each section or sub-section under the heading "Specifications". In some cases reference must also be made to these "Specifications" for model application and methods of distinguishing the various design and construction differences.

Manufacturer's model or part numbers are used in many instances in the "Specifications" tabulations. These numbers are provided primarily for unit identification or truck model application reference, and should be referred to when ordering parts. All detail service part numbers must be obtained from the applicable Parts Book.

SPECIAL TOOLS

Special tools and equipment are mentioned, and in many instances illustrated, throughout the text. These tools are specially designed to accomplish certain operations efficiently and readily. Such tools are mentioned in the text by tool vendor's numbers.

Information regarding availability of these tools can be obtained from your Zone Office, or directly from the Service Publications Department, at Central Office.

OPERATION

Operating instructions from the standpoint of the driver are included in a booklet entitled "Owner's and Driver's Manual" which is placed in the cab of every new truck.

ALPHABETICAL INDEX

Important subjects, with manual page number references, are alphabetically listed in the Index in the back of this manual.

Courtesy of General Motors Corporation

1977 SERVICE MANUAL

SERIES 70 THRU 9502

EXCEPT M, N

9003—9502

NOTE

When reference is made in this manual to a brand name, number, or specific tool, an equivalent product may be used in place of the recommended item.

Courtesy of General Motors Corporation

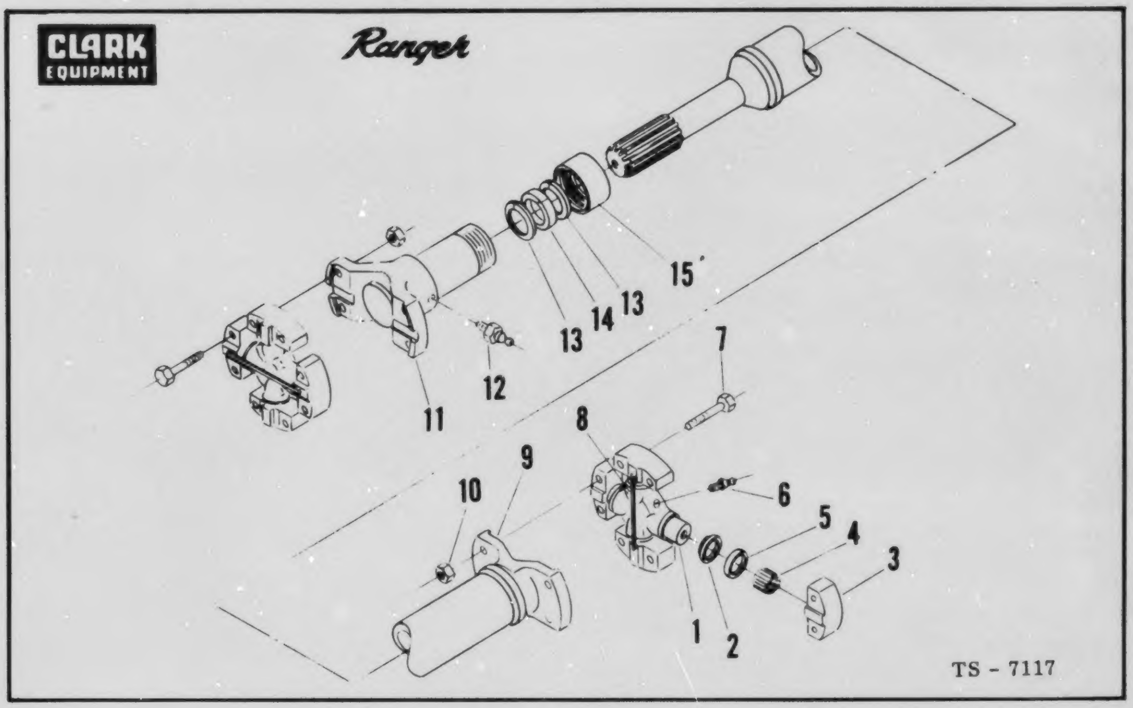
TABLE OF CONTENTS

SEC.	NAME
0	**GENERAL INFORMATION** 0A. General Information 0B. Lubrication
1	**HEATING & AIR CONDITIONING** 1A. Heating 1B. Air Conditioning
2	**FRAME AND CAB** 2A. Frame and Body Mounts 2B. Cab Maintenance 2C. Steel Conventional Cab 2E. Aluminum Tilt Cab 2G. Sheet Metal and Fiberglass
3	**STEERING, SUSPENSION, WHEELS AND TIRES** 3A. Front End Alignment 3B. Steering 3C. Front Axle and Suspension 3D. Rear Suspension 3E. Wheels and Tires
4	**REAR AXLE AND PROPELLER SHAFT** 4A. Rear Axle 4B. Propeller Shaft
5	**BRAKES** 5B. Air Brakes 5D. Air Compressor and Governor
6	**ENGINE** 6A. Engine Mechanical 6B. Cooling 6C. Fuel System 6D. Engine Electrical 6E. Emission Controls 6F. Exhaust
7	**TRANSMISSION & CLUTCH** 7A. Automatic Transmission 7B. Manual Transmission 7C. Clutch
8	**CAB AND CHASSIS ELECTRICAL**
	SPECIAL TOOLS
	INDEX

Parts Books

Besides a service manual, heavy duty equipment has a parts book. Parts books illustrate components in exploded-view diagrams (Figure 1-1). In the diagram the parts are given a reference number and the reference key gives the part number, a description of the part, and the quantity needed.

Parts books, like service manuals, have introductory sections explaining how to use the book. A typical example from a Case Parts book is shown below.



PROP SHAFTS - DOUBLE

Item	Part No.	Qty.	Description
A	1900059	1	Prop shaft, front axle input
B	944862	2	Spider and bearing ass'y. (Incl. items 1-6, 8)
C	940093	1	Slip yoke ass'y. (Incl. items 11 & 12)
1	N.S.S.	2	Spider (See item B)
2	N.S.S.	8	Seal, dust (See item B)
3	N.S.S.	8	Bearing (See item B)
4	N.S.S.	248	Roller (See item B)
5	N.S.S.	8	Seal and retainer (See item B)
6	10H-35	2	Fitting, grease
7	940089	16	Bolt
8	N.S.S.	4	Wire, weld (See item B)
9	1990114	1	Tube assembly
10	8D-06	16	Nut
11	N.S.S.	1	Slip yoke (See item C)
12	10H-25	1	Fitting, grease
13	940091	2	Washer, retainer
14	940092	1	Washer, felt
15	940090	1	Retainer

(1-1)

Courtesy of Clark Equipment Company

GENERAL INFORMATION

INDEXES

This Parts Catalog is arranged for easy identification of Genuine CASE Service Parts. An alphabetical index is provided at the front of this Catalog to locate the major groups or assemblies. A numerical index at the rear of the Catalog gives the part numbers and the pages on which they are described.

ILLUSTRATIONS

All parts are illustrated in "Exploded Views" which show the individual parts in their normal relationship to each other. Reference numbers are used in the illustrations. These numbers correspond to those in the "Reference Number" column and are followed by the part number, description and quantity required.

ORDERS

Orders should plainly specify correct part number, full description, quantity required, machine model and engine model, machine and engine serial numbers, method of shipment and shipping address.

CHANGES

When changes to the machine make it necessary, revised pages for this book will be issued. The revised pages will be issued with the same page number as those they replace and the "Issue" number and date will be advanced.

It is imperative that revised Parts Book pages be inserted into their respective Parts Books as soon as received. Failure to do so will lead to confusion and defeat the purpose of the book.

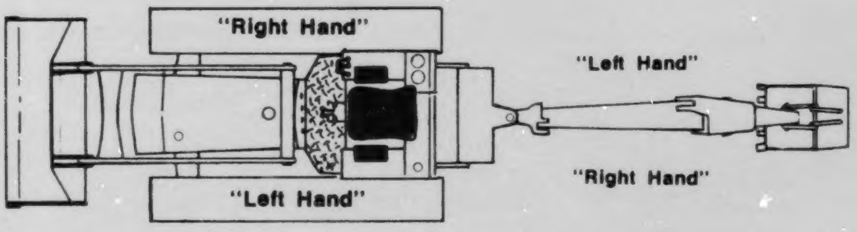
INDENTED DESCRIPTION

Indented parts in the description list are a part of the preceding assembly or sub-assembly. The quantity shown in the "Number Required" column is the number of parts used on a machine except where parts are indented in descriptive list. In this case the quantity shown is the number required for the preceding assembly or sub-assembly.

REF.	PART NO.		DESCRIPTION	REQ'D.
	A	55159	CYLINDER ASSY. - rear steering	1
28	A	56208	SOCKET ASSY. - rear cylinder	1
29	A	55956	PLUG - adjusting, socket assy.	1
30	A	55957	SEAT - socket ball	2
31	A	56210	SPRING - socket	1
32	A	56209	SEAT - socket spring	1
33	G	45175	CLAMP ASSY. - socket assy.	1
34	16-	836	HHCS - 1/2" - 20 NF × 2-1/4"	1
35	132-	104	PIN - cotter, 3/16" dia. × 3"	1

TERMS "RIGHT HAND" AND "LEFT HAND"

"Right Hand" and "Left Hand" sides of the crawler are determined by sitting in the operator's seat facing the direction of forward travel. "Right Hand" and "Left Hand" sides of the backhoe are determined by sitting in the operator's seat facing the backhoe.



B670168
Issued March, 1968

Courtesy of J.I. Case

Parts Lists

You will be expected to write parts lists for the machinery you work on. Some general points about parts lists are:

1. Always include with any parts list the make, model, and serial number of the machine. This is the most important piece of identification on heavy duty equipment. Also, when ordering parts, for example for an engine or transmission, include their serial numbers as well. Location of serial numbers on a Case crawler tractor are shown in Figure 1-2.
2. Name the component that the parts come from and, as mentioned above, the serial number of the component if it has one.
3. When referring to a part or component write the name that the manufacturer uses in the service manual or parts book, rather than the name you personally may use for it.
4. When listing the parts, keep the related items together, i.e., don't give a bearing, then a gear, then a gasket and back to another bearing. This makes the list hard for a parts person to follow, and increases the chances of missing a part.
5. State the quantity of each part required.
6. When parts are received, check immediately for quantity, correctness and condition of parts. Advise the distributor of any error, and make claims for any shipping damages immediately with the carrier.
7. There are three situations you can be faced with when ordering parts:
   (a) Parts book is available: this is fairly straight forward as you just list the part numbers from the parts book as in the example below:

   Case Crawler Loader: Model — 1150, Serial #7108999. Parts for a Track Roller:

1 only	#36406	Shaft
2 only	#36043	Bushing
2 only	#35267	Seals
2 only	#30116	Bearing cones
2 only	#55807	Bearing cups
4 only	#31329	Shims
1 only	#36465	Hub — double flange

   (b) Parts book is not available, but the part is stamped: record the number stamped on the part, mentioning that this is where the number is taken from (See the example for (c)).

   (c) No parts book and no number stamped on the part: parts for which you have no numbers must be described as shown below:

   Clarke Ranger Skidder Series 600

   Serial Number — C-9046-240

   Rear wheel planetary final drive and hub

Parts Required:

1 only hub inner oil seal

1 only hub inner bearing cone — (number on bearing) 799408

1 only hub inner bearing cup — (number on bearing) 658985

1 only hub outer bearing cone — (number on bearing) 672181

1 only hub outer bearing cup — (number on bearing) 672182

1 only axle shaft (left side)

1 only sun gear

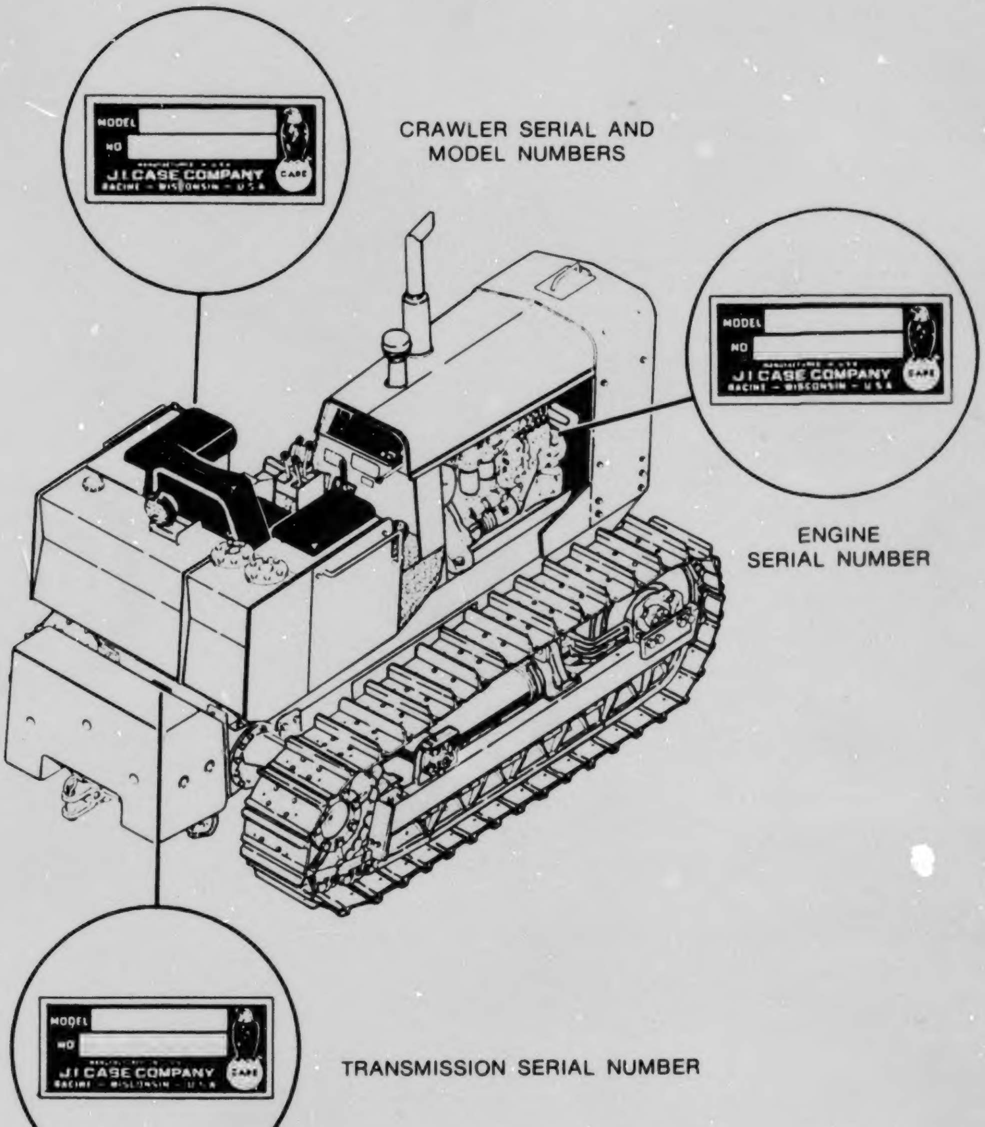
1 only internal gear

3 only planet pinion gears

3 only planet pinion gear shafts

6 only planet pinion thrust washers

MODEL 1150 INDUSTRIAL CRAWLER TRACTOR
SERIAL NUMBER LOCATIONS


CRAWLER SERIAL AND MODEL NUMBERS
ENGINE SERIAL NUMBER
TRANSMISSION SERIAL NUMBER
MODEL
NO
J.I. CASE COMPANY
RACINE - WISCONSIN - U.S.A
CASE

(1-2)

Courtesy of J.I. Case

Service Report

A service report should be short and concise. A service report written before a repair is made should contain:

1. What is to be worked on, and what is wrong with it.
2. List the parts needed.
3. Statement to the effect that with the parts listed the component can be rebuilt.

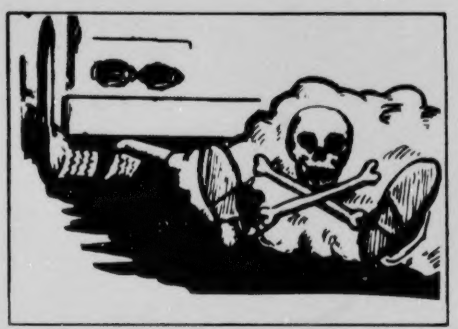
A service report written after repair is done should:

1. List the parts used.
2. Briefly state what work was done.

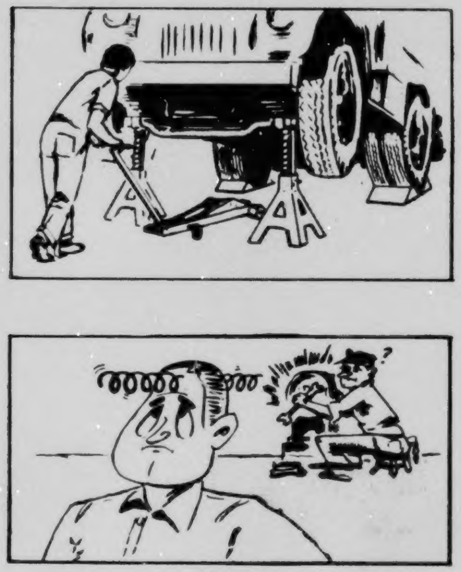
An example of a service report satement for the Clarke Skidder mentioned under the section, Parts List, is given below (note that the lists of parts would be included in the report, in addition to the make, model and serial number of the machine):

> "When the left rear final drive was disassembled and inspected, the parts listed were found to be worn or damaged to the point of needing replacement.
>
> The spindle, hub, cover and wheel assembly are all in good condition. In my opinion it is economical to rebuild this final drive."

Although service reports are discussed here, it should be pointed out that the apprentice or for that matter journeyperson, in many cases, will be given a work order and will not have a say in what work is to be done. However, when carrying out the work order, always bring to the attention of your supervisor other work that you find needs doing. Disregarding it and following only the work order does not make a responsible mechanic.

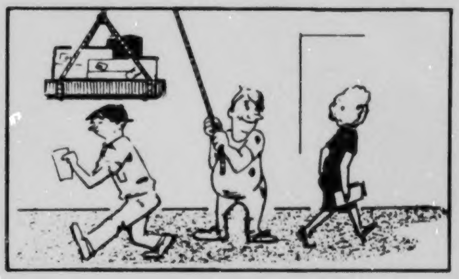


CARBON MONOXIDE — THE QUIET KILLER!



(1-3)

Courtesy of Mack Truck of Canada Limited



(1-4)

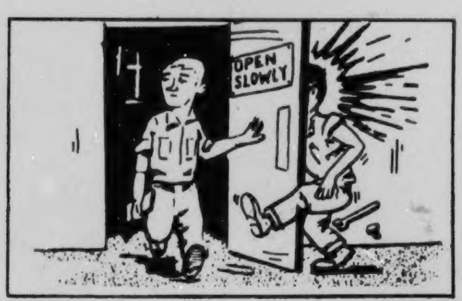
Courtesy of Mack Truck of Canada Limited

SHOP SAFETY

Most accidents don't just happen: they are caused by carelessness. Always be concerned with your own safety and with that of others around you. The following cautions and illustrations (courtesy of Mack Truck of Canada Limited) show how ignoring common safety rules can cause injury, even death.

GENERAL SAFETY PRACTICES IN THE SHOP

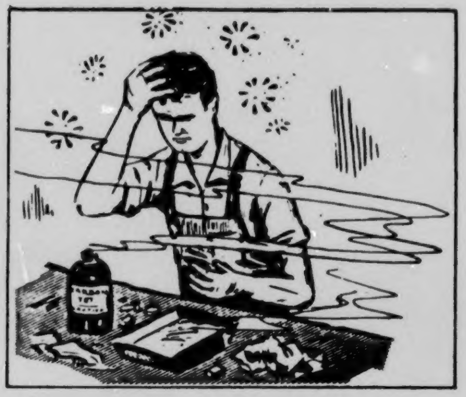
1. Do not run engines in enclosed areas without adequate ventilation (Figure 1-3).
2. When checking the coolant, turn the pressure cap slightly to release pressure before removing the cap.
3. When raising a vehicle, chock the wheels, and use a jack of sufficient capacity. Do not extend the jack beyond its safe limits. Be sure the vehicle's handbrake is set (Figure 1-3).
4. When working under a vehicle, use axle stands or rigid jacks, after raising the vehicle to working height. Wear goggles whenever needed; a drop of high-detergent oil or other fluid could cause the loss of your sight.
5. Know what to expect from a part before dissassembling it. A hidden spring-loaded ball or shaft, can be a lethal weapon, maybe not to you, but to someone else in the near vicinity (Figure 1-3).
6. Always shut off a machine before attempting repairs, cleaning, adjusting.
7. Stay out from under a suspended load (Figure 1-4).
8. Open doors slowly otherwise, you could seriously injure someone (Figure 1-5).



(1-5)

Courtesy of Mack Truck of Canada Limited

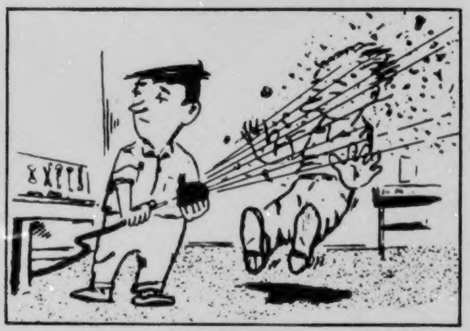
9. Watch for other floor traffic when moving material, especially at blind openings.
10. Do not use carbon tetrachloride for cleaning. This fluid can cause serious internal injury, even death, if its fumes are inhaled (Figure 1-6).



(1-6)
Courtesy of Mack Truck of Canada Limited

11. Take precautions with compressed air and gases:

    Do not use air pressure for cleaning your clothes or body. Serious injury to yourself and others who are in the jet stream may result (Figure 1-7).



(1-7)
Courtesy of Mack Truck of Canada Limited

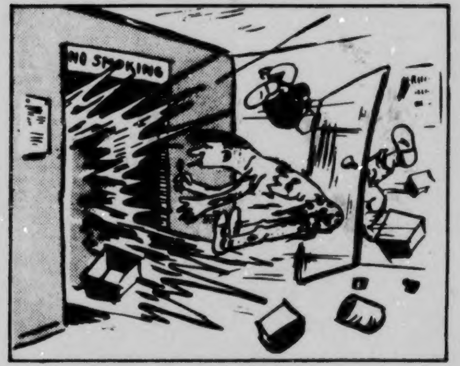
- — never horse play with an air hose
- — know the procedure for tapping a new tank of any compressed gas before attempting the job
- — use a spray mask when spray painting.

12. Clean up spills immediately. Knees and backs have been thrown out when people have stepped unexpectingly on spilled fluid and slipped.
13. Keep jack handles up where they won't be tripped over.
14. Stand creepers up when not in use.
15. Keep work areas as tidy as possible. Cluttered surroundings can cause accidents.

FIRE PREVENTION PRACTICES

Carelessness is the major cause of fire and explosion in repair shops. Fire prevention practices are listed below.

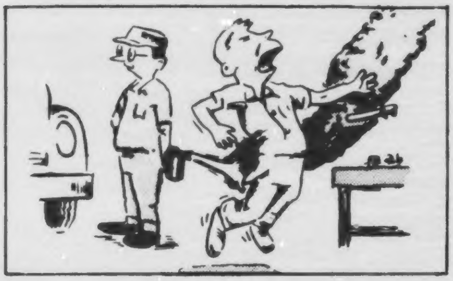
1. Keep all inflammable fluids and materials in their proper containers.
2. Heed **No Smoking** signs. They are there for a purpose (Figure 1-8).



(1-8)
Courtesy of Mack Truck of Canada Limited

3. When discarding a cigarette, don't flip it: make sure it is out. Use an ashtray or container.
4. Keep fire doors clear: don't block them.
5. Keep fire fighting equipment in good operating condition:
    - — Test fire hoses at regular intervals.
    - — Extinguisher pressure should also be checked at regular intervals. Many modern extinguishers have a pressure gauge that tells when they need recharging.
    - — Refill extinguishers immediately after they have been used.

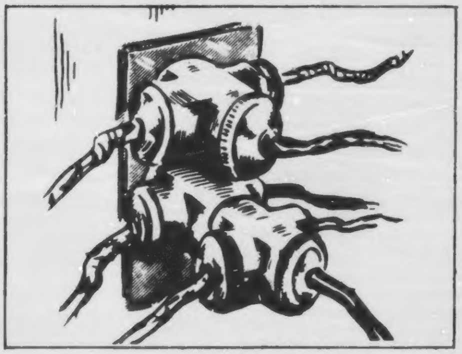
6. Watch where you point a lighted torch. You could injure someone (Figure 1-9), or light the place on fire.



(1-9)

Courtesy of Mack Truck of Canada Limited

7. Do not overload any one circuit with plugs. Octopus connections (Figure 1-10) are dangerous.



(1-10)

DANGEROUS OCTOPUS CONNECTIONS

Courtesy of Mack Truck of Canada Limited

8. When using an extension light under a vehicle, protect the lamp from breaking with a lamp guard. Lamps breaking near accumulated oil or fuel have caused many fires.
9. Keep a fire extinguisher handy when welding. One small hot spark from a welding torch can set off a major fire.
10. Good housekeeping is important in preventing fires. Keep the floor clean and clean up spilled combustible fluids such as gasoline and oil immediately. Oily rags can ignite spontaneously: keep them in a closed metal container, or better still, dispose of them.
11. Gasoline is very volatile; its vapors can be set off by a spark. When working on or near a fuel system, be very careful not to do anything that would cause a spark.
12. Clean with non-inflammable solvents, which are non-toxic and of high flash point (100°F. or more). Do not use questionable cleaning fluids in the vicinity of open flames (such as welding operations) or high heat sources. Petroleum-based solvent is most commonly used in the trade for washing parts, although diesel fuel is also used for this purpose. Hot and cold caustics are also used for washing in some shops; they must be used with caution. If your shop has a caustic wash tank obtain instructions for its proper use.

IN CASE OF FIRE

Fires have been divided into four main classes: A, B, C and D. The extinguishers used to fight these fires are similarly classed as an A, B, C or D Extinguisher.

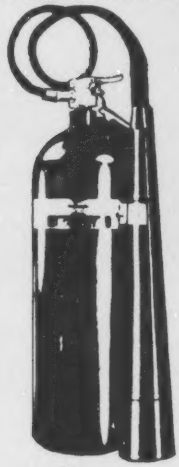
Class "A" Fires — occur in ordinary combustibles such as wood, paper and textiles. They are best extinguished by cooling below the burning point with water or an extinguisher which has "A" on its lable.

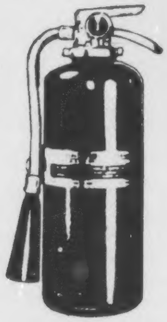
Class "B" Fires — occur in gasoline, oils and other petroleum products. Extinguish such fires by smothering (i.e., depriving them of oxygen). Smothering can be accomplished by using a "B" extinguisher, a wet blanket, sand, CO_2 (carbon dioxide) or in some cases, a lid covering.

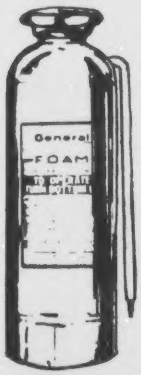
Class "C" Fires — occur in live electrical appliances and equipment. To put out an electrical fire a non-conductor type of extinguishing agent is used. DISCONNECT the power supply before applying any extinguishing agent. Use an extinguisher labelled "C". Note that often when the electricity is disconnected, a class "C" fire often reverts to a Class "A" or "B" fire.

Class "D" Fires — occur in certain combustible metals. To fight these high intensity fires use a dry chemical "D" extinguisher. Note that "D" fires are not likely to occur in repair shops.

Locate the fire extinguishers in your shop. All extinguishers have directions for use printed on the cannister, and include the letters referring to the type of fire they can be used on. Study these directions beforehand so that you will be prepared for an emergency. If a fire occurs, you won't have time to waste studying directions how to use the extinguisher. The type of extinguishers you are likely to find in a mechanical shop are illustrated in Figure 1-11.

Type	Contents	Kinds of Fire	How to Start	Discharge
CARBON DIOXIDE 	Liquid Carbon Dioxide under pressure.	CLASS B (oil, gasoline, paint, grease)	Pull pin and open valve	6 to 8 feet about 42 sec. (15-lb. size)

Type	Contents	Kinds of Fire	How to Start	Discharge
DRY CHEMICAL 	Bicarbonate of soda with other dry chemicals and cartridge of carbon dioxide gas	CLASS B These extinguishers also have some effect on CLASS A FIRES (wood, paper, textiles)	Three types: Pull pin or collar, then 1) Open valve or 2) Press lever or 3) Turn over and bump then squeeze nozzle.	About 14 feet 22 to 25 sec. (30-lb. size)

Type	Contents	Kinds of Fire	How to Start	Discharge
FOAM 	Solution of aluminum sulfate and bicarbonate of soda	CLASS A and CLASS B (oil, gasoline, grease, paint)	Turn over	for 2½ gal. size 30 to 42 feet 50 to 55 sec.

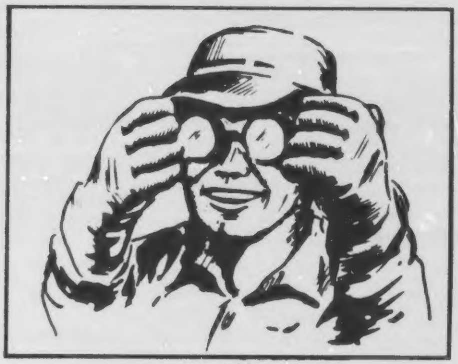
(1-11) FIRE EXTINGUISHERS

Courtesy of Mack Truck of Canada Limited

PERSONAL SAFETY

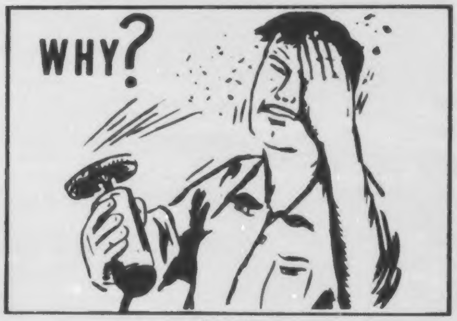
Eyes

The Workers' Compensation Board, states that properly fitting goggles (Figure 1-12), face shields or other eye protective equipment, appropriate to the work being done, must be worn when performing any work in which there is a hazard of eye injury (Figure 1-13). Remember there are no second chances with eyes: sight cannot be restored. Note that there are 14 companies in North America making glass eyes.



(1-12)

Courtesy of Mack Truck of Canada Limited

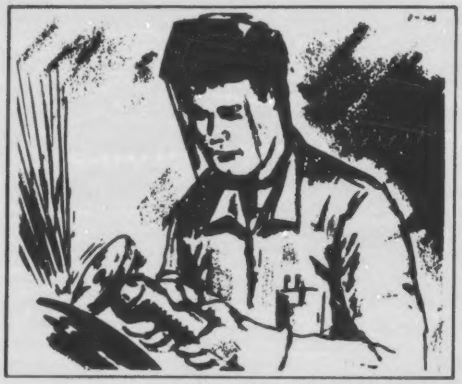


(1-13)

Courtesy of Mack Truck of Canada Limited

Use a face shield or goggles when:

1. Grinding (Figure 1-14).
2. Hammering on hardened surfaces with a ball peen hammer.
3. Electric welding (shield), acetylene (goggles).
4. Chipping with a hammer and chisel. Also, you should put up some type of screen, to protect others nearby from flying bits.
5. Operating a steam cleaner or dipping parts in a cleaner.

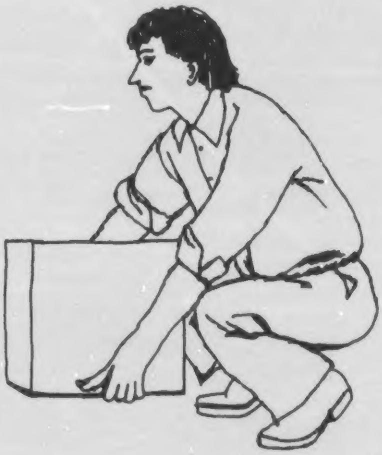


(1-14)

Courtesy of Mack Truck of Canada Limited

Back

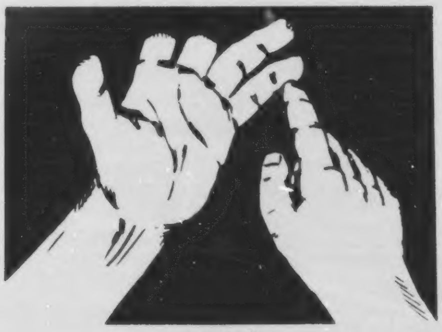
1. Don't overestimate your strength. Many back strains have been caused by people lifting something that was too heavy for them. Get help with heavy objects, or use a lifting device.
2. Lift from a squatting position with the back straight (Figure 1-15). Never reach and lift.
3. Push a heavy object: don't pull it.



(1-15)

Hands

Your hands are the most important tools you have. Protect them. Remember it's hard to count to ten on your hands when some of the digits are missing (Figure 1-16).

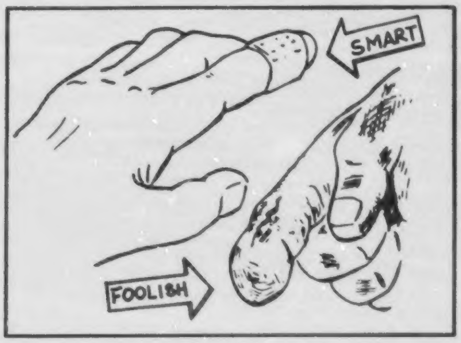


(1-16)

Courtesy of Mack Truck of Canada Limited

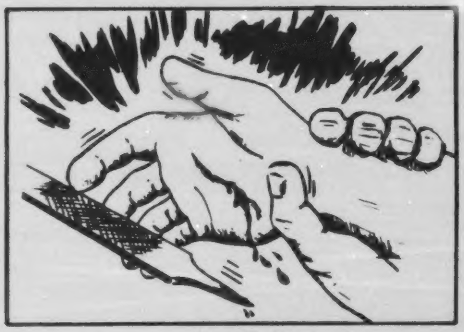
Look after your hands:

1. Use gloves on jobs that require them.
2. Use the guards provided on all machinery.
3. Take proper care of nicks, cuts, and scratches: blood poisoning can result from the slightest scratch. Treat cuts with first aid (Figure 1-17). It's better to be sure today than hospitalized tomorrow.
4. Sweep up broken glass: don't try to pick up the pieces with your hands.
5. Wash hands thoroughly. Stop skin trouble before it starts.
6. Never use a file or rasp without a handle (Figure 1-18).



(1-17)

Courtesy of Mack Truck of Canada Limited



(1-18)

Courtesy of Mack Truck of Canada Limited

7. One of the best ways to protect your hands is to use the proper tool for the job. Being too lazy or impatient to get the right tool is a good way to smash up your hands.
8. Never have a loose sleeve, tie, or shirttail when operating a machine or working around a moving machine. Your hand or body could get drawn into the machine with some pretty horrible results.

Feet

The Workers' Compensation Board, states that safety-toed shoes must be worn in any occupation where there is a danger of injury to the toes. In accordance with this law, heavy duty mechanics should wear safety boots.

Head

The Workers' Compensation Board, states that a hard hat must be worn in work areas where there is a potential hazard to the head from falling, flying or thrown objects or from other harmful contacts. Many companies that employ heavy duty mechanics now specify that hard hats must be worn. Signs such as **Hard Hat Area** are posted, and everyone must wear a hard hat in that area. In most mills, manufacturing plants, mines, logging areas, and construction camps this is usually the rule.

Ears

Hearing is as important as sight. It's as common nowadays to see sound muffs being worn as it is hard hats. When working around machinery, noise levels can reach a level that causes short-term deafness. Continued exposure to these levels can cause long term deafness. Always wear ear protection when working in areas of high noise levels.

HAND TOOLS

This section is intended as a basic introduction to hand tools. For more detailed information, there are several good tool books on the market. One of these is **Peterson's Tool Book No. 1, Basic Automotive Tools and How to Use Them.**

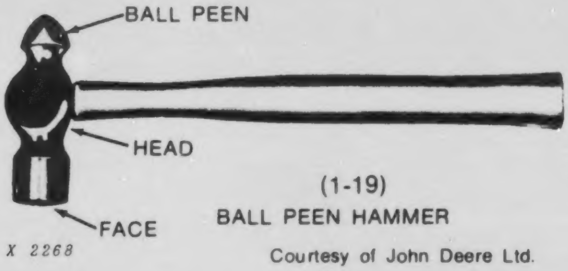
HAMMERS

Ball Peen Hammers (Figure 1-19): are frequently used by shop servicemen. The flat face is for hammering and the ball part is for rounding off rivets and similar jobs. They are available in various sizes rated according to their weight.

Soft Hammers (Figure 1-20): are used in place of steel hammers to protect machined surfaces or fragile parts. These hammers are commonly made of lead, rawhide, plastic, brass or rubber.

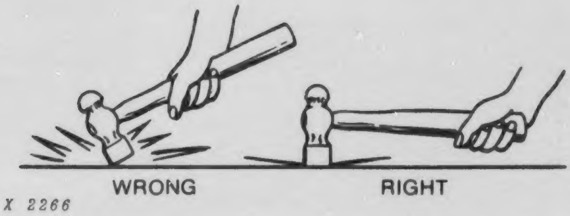
Correct Use

1. The proper grip and striking angle of a hammer are illustrated in Figure 1-21.
2. If the wedge in the hammer handle starts to come out, drive it in again to tighten the handle. If the wedge is lost, replace it before using the hammer. Never work with a hammer having a loose head.
3. Never use a steel hammer on a machined surface: use a soft hammer.



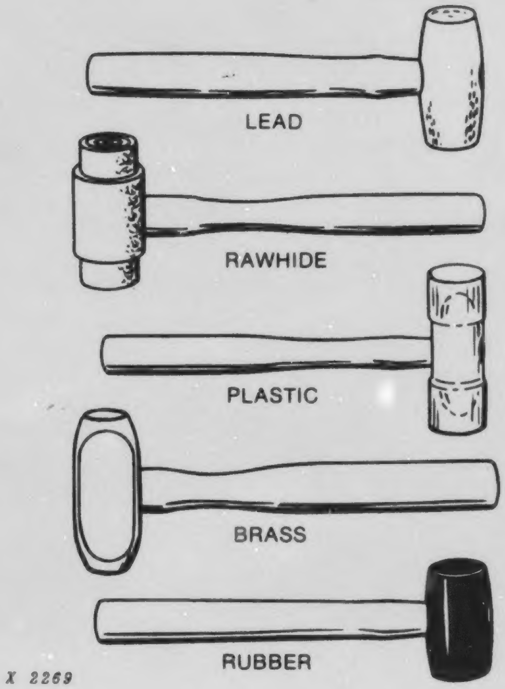
(1-19)
BALL PEEN HAMMER

Courtesy of John Deere Ltd.



(1-21) CORRECT USE OF A HAMMER

Courtesy of John Deere Ltd.

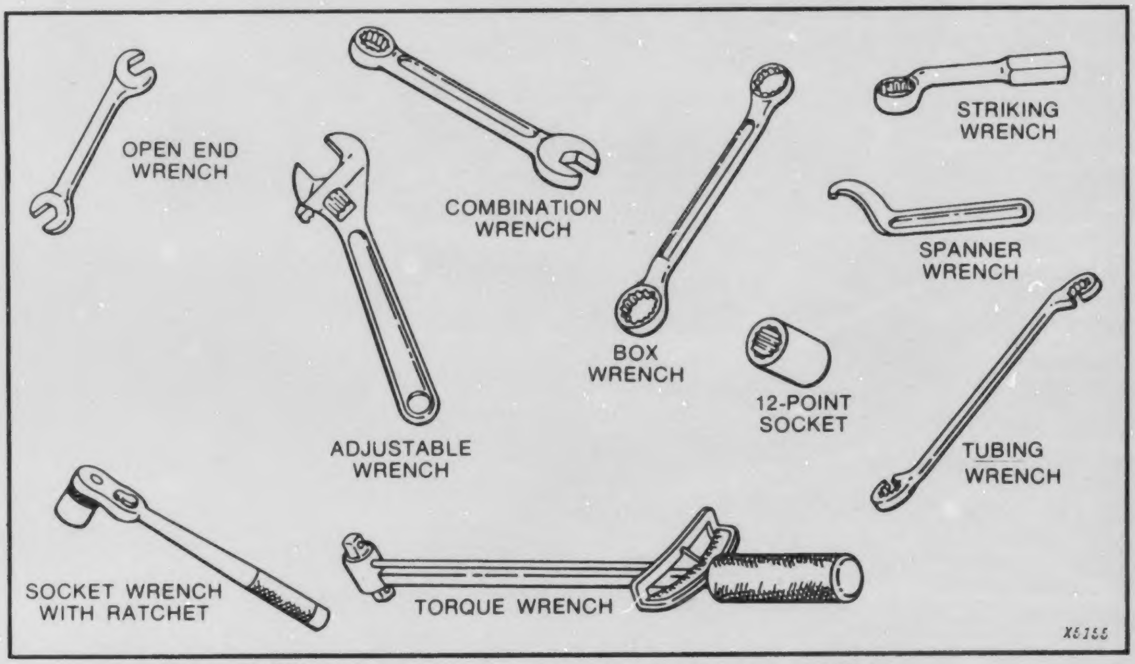


(1-20) SOFT HAMMERS

Courtesy of John Deere Ltd.

WRENCHES

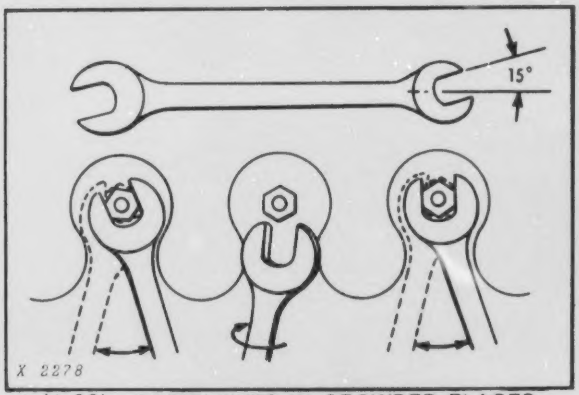
Common wrenches are illustrated in Figure 1- 22.


OPEN END WRENCH
COMBINATION WRENCH
STRIKING WRENCH
SPANNER WRENCH
ADJUSTABLE WRENCH
BOX WRENCH
12-POINT SOCKET
TUBING WRENCH
SOCKET WRENCH WITH RATCHET
TORQUE WRENCH
X5155

(1-22) **Common Wrenches For Bolts, Cap Screws, and Nuts**

Courtesy of John Deere Ltd.

Open-End Wrenches: have openings at either end of close but different sizes. The openings are offset so that the wrenches can be flopped to give them more swing in cramped spots (Figure 1-23). Note: never hammer on a standard wrench. Hammer only on a striking wrench. Also don't use a bar or pipe to increase leverage on a wrench. Use a pipe only when an extension is needed because the nut is hard to reach.

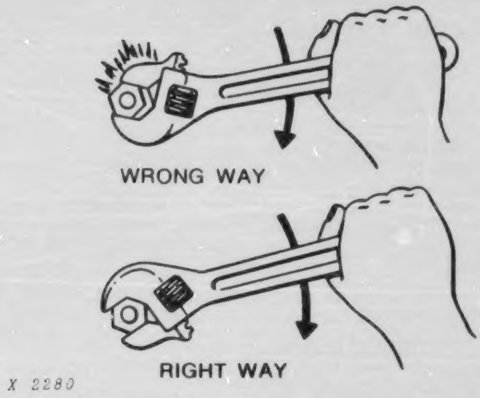


(1-23) LOOSEN NUTS IN CROWDED PLACES BY "FLOPPING" THE WRENCH

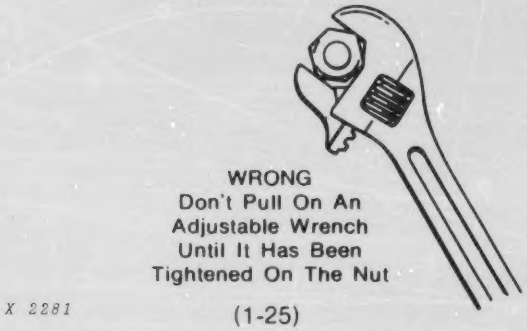
Courtesy of John Deere Ltd.

Adjustable Open-End Wrenches: have a sliding jaw that is moved by an adjusting screw. Adjustable wrenches should mainly be used when an odd sized nut or bolt is encountered; otherwise an open-end wrench should be used. These wrenches aren't intended for hard service: treat them with care. When using an adjustable wrench:

1. Always place the adjustable wrench on the nut so that the pulling force is applied to the stationary jaw side of the wrench (Figure 1-24). This side can withstand much greater force.
2. After placing the wrench on the nut, tighten the adjusting screw so that the wrench fits the nut snugly (Figure 1-25). If the jaws are loose, they will round off the nut.
3. Keep the wrench clean. Wash it occasionally in cleaning solvent and apply a light oil to the adjusting screw and slide.


WRONG WAY
RIGHT WAY
X 2280

(1-24) Courtesy of John Deere Ltd.

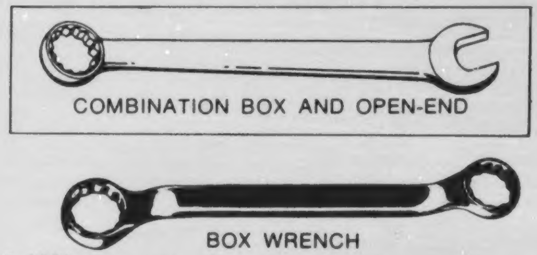

WRONG
Don't Pull On An
Adjustable Wrench
Until It Has Been
Tightened On The Nut
X 2281

(1-25)

Courtesy of John Deere Ltd.

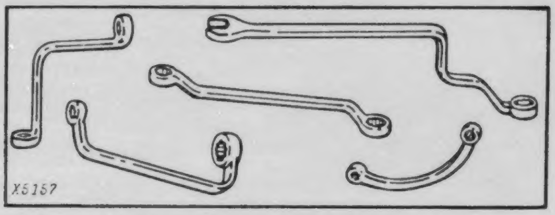
Box Wrenches: both six and twelve point box wrenches (Figure 1-26) are available, but twelve point are most common. Box wrenches are sometimes referred to as 12-point wrenches. Because of their 12-points, box wrenches can turn with a minimum swing of 15 degrees compared with 30 degrees or 60 degrees for an open-end wrench.

Box wrenches won't slip off a nut since they completely surround the nut. Combination box and open-end wrenches can speed up nut and bolt installations. The box end is used to break loose or snug down the nut, while the open-end is used for greater speed for the rest of the turning. These combination wrenches are the most popular hand wrenches.


COMBINATION BOX AND OPEN-END
BOX WRENCH
X 2282

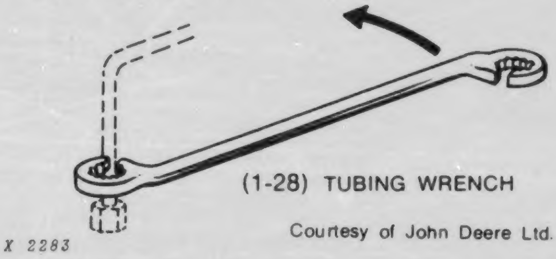
(1-26) BOX WRENCHES
Courtesy of John Deere Ltd.

Special open-end and box wrenches come in many different shapes and thicknesses (Figure 1-27) for jobs where nuts or bolts are difficult to remove with ordinary wrenches.



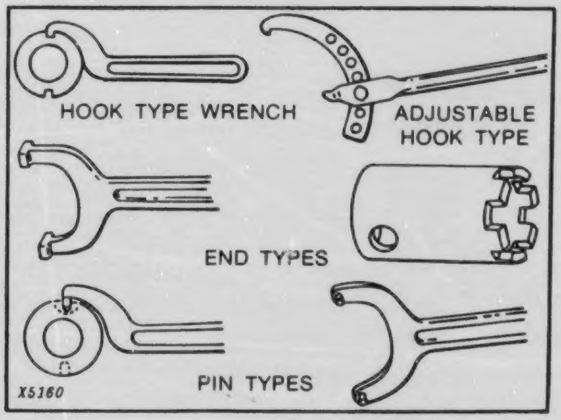
(1-27) VARIATIONS OF BOX AND COMBINATION WRENCHES
Courtesy of John Deere Ltd.

Tubing Wrench: has an opening that fits over hydraulic tubing. Tubing wrenches can only be pulled in one direction; pulling in the other direction, allows the jaw to ride over the nut. Tubing wrenches are available in six and twelve points.



(1-28) TUBING WRENCH
Courtesy of John Deere Ltd.

Spanner Wrenches: are usually special tools supplied with a machine. Some types of spanners are illustrated in Figure 1-29.


HOOK TYPE WRENCH
ADJUSTABLE HOOK TYPE
END TYPES
PIN TYPES
X5160

(1-29) VARIATIONS OF SPANNER WRENCHES
Courtesy of John Deere Ltd.

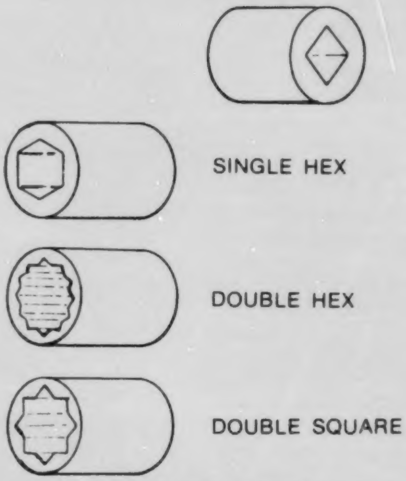
SOCKET WRENCHES

Modern socket wrenches have done more to make a mechanic's job easier and faster than any other tool. A full socket wrench set contains sockets as well as various accessories that allow the sockets to be put to best advantage.

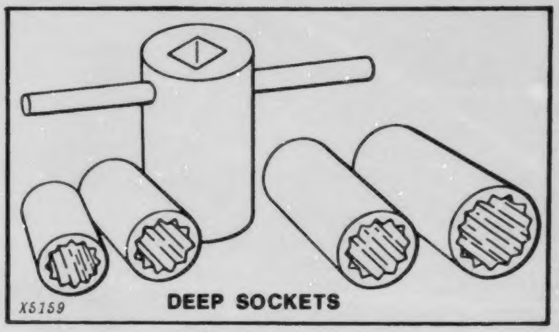
Several types of sockets are available (Figure 1-30): single-hex sockets have 6-points; double-hex sockets have 12-points; double square sockets have 8-points (for use on square nuts). Extra deep sockets (Figure 1-31) are made to remove spark plugs or nuts that are a long way down on the bolts, such as U-bolts. Each socket has a square hole in its top (Figure 1-30) to accept any one of a variety of drive units. The square lug of the drive unit comes in standard sizes of 1/4, 3/8, 1/2 and 3/4 inch. The sizes most often used are 3/8 and 1/2 inch. Heavy duty 1 inch and 1-1/2 inches are also made.

Socket wrench accessories (Figure 1-32) are described below:

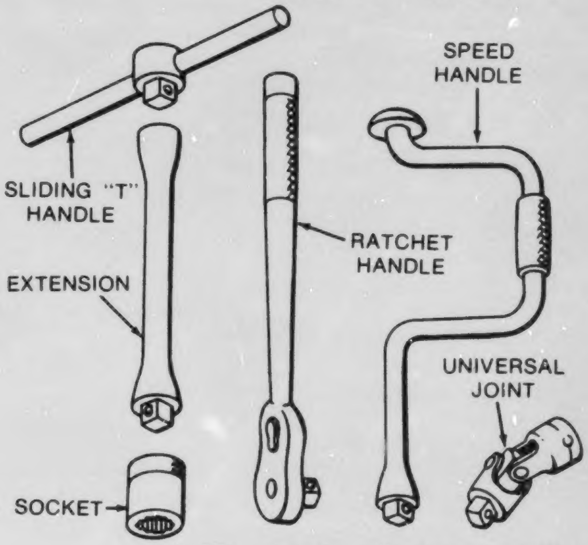
1. The speed handle is used for quickly installing or removing loose nuts that spin freely. However, it does not allow enough twisting force for final tightening.
2. The ratchet allows a nut to be removed without lifting the socket off the bolt. Ratchets can be set so that they will pull in both tightening and loosening directions.
3. A universal joint is used to work on nuts in places where a straight wrench won't reach. With a universal joint the wrench handle can be worked at an angle with the socket.
4. A sliding "T" handle and extension can be used where there isn't space to get the ratchet handle in.
5. A torque wrench is another socket set accessory. Torque wrenches are discussed separately.
6. Adapters are available that accommodate a ratchet to different size sockets (1/4, 3/8, 1/2, 3/4 inch).
7. Flex handles are used for the hard pulling when disassembling and reassembling components. Generally, flex handles are about twice the length of the ratchet handle.



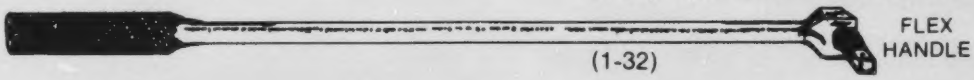
(1-30) TYPE OF SOCKETS
Courtesy of John Deere Ltd.



(1-31) Courtesy of John Deere Ltd.



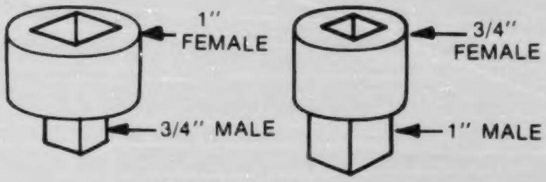
(1-32) SOCKET SET ACCESSORIES



(1-32)

Adapters

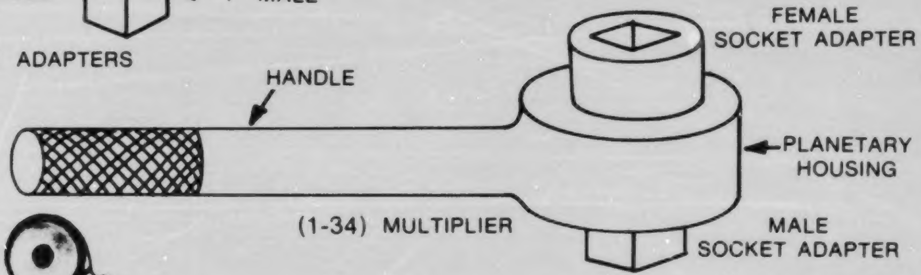
Adapters are used to change the wrench or socket drive size up or down one size. For example, if you have a 1-inch drive flex handle and want to use a socket for a 3/4 drive set, use a 1-inch to 3/4 inch adapter (Figure 1-33). Conversely, if you want to use a 1 inch drive socket on a 3/4 inch drive flex handle, use a 3/4 inch to 1 inch adapter.



(1-33) ADAPTERS

Multipliers

Multipliers (Figure 1-34) are socket wrench attachments that give a mechanical advantage. A multiplier consists of a handle, a small planetary housing and male and female square socket adapters. To use a multiplier, install a flex handle or ratchet into the female adapter and a socket onto the male adapter. Hold the handle of the multiplier with one hand, and turn the flex handle or ratchet with the other. The socket is turned at a reduction thus multiplying the force applied to the sockets. Multipliers are available in 3/4 inch and 1 inch drive sizes with a torque multiplication of 4 : 1.

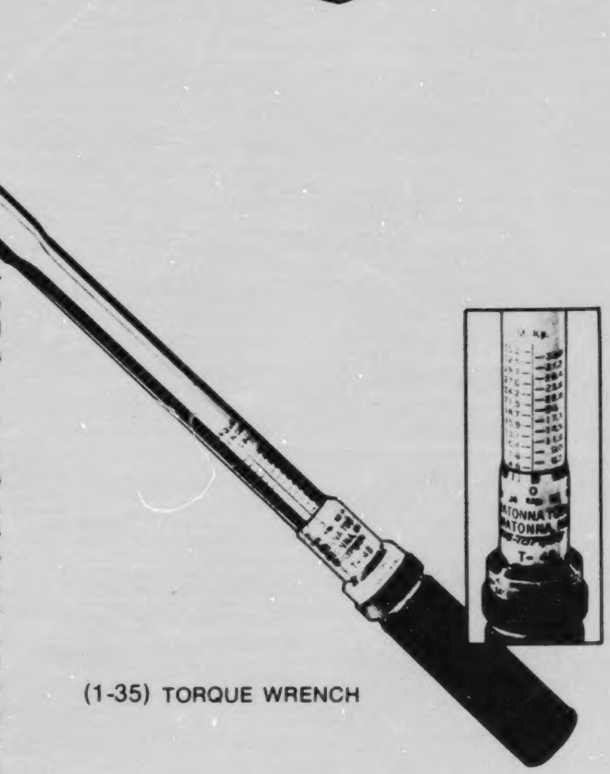


(1-34) MULTIPLIER

TORQUE WRENCHES

On modern machinery, torquing bolts is an important procedure. Uneven torquing can cause warping, leaks, cracks, and stressed areas. Under and over torquing also causes problems. Thus the need for torque wrenches.

Torque wrenches (Figure 1-35), like other wrenches, tighten or apply torque to a nut, but there is a difference. With ordinary wrenches you rely on touch or feel to tell if a nut is tight, whereas with a torque wrench a scale gives exactly how much torque has been applied to the nut. Torque wrenches take the guesswork out of tightening nuts. You look up in the service manual what torque should be applied, then turn the torque wrench until the scale reaches the recommended value. Most torque wrenches have a signalling device: the desired torque is set on an indicator and when that torque is reached the wrench gives a signal. There are a number of good torque wrenches on the market, and it's a matter of personal preference which to buy.



(1-35) TORQUE WRENCH

Courtesy of Owatonna Tool Company

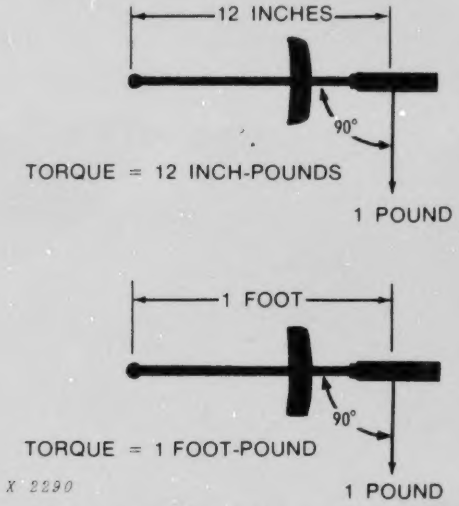
Torque

Note that the recommended torques in service manuals are calculated according to this law: For a bolt to stay tightened, it must be tightened enough so that the load in the bolt is greater than the loads which the bolt must absorb during operation.

Torque is simply the lever principle of force being applied at a distance. Torque is measured in foot-pounds if the distance is measured in feet, or inch-pounds if the distance is measured in inches (Figure 1-36). To change foot-pounds to inch-pounds or vice versa, use the following formulas:

Foot-pounds multiplied by 12 = inch-pounds

Inch-pounds divided by 12 = foot-pounds



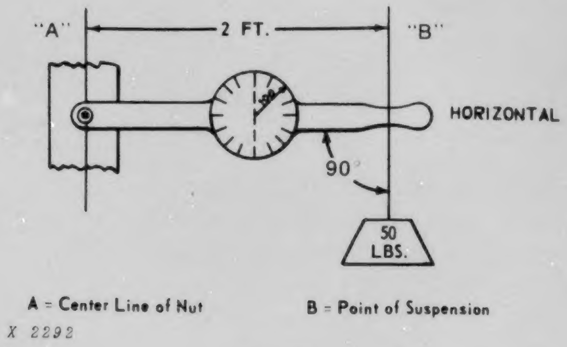
(1-36) UNITS FOR MEASURING TORQUE
Courtesy of John Deere Ltd.

To torque nuts accurately, it is important to select the proper size (i.e., capacity) torque wrench for the job. A good rule of thumb is to select a torque wrench so that your working range is within the middle two quarters of the scale. For example, for nuts requiring between 150 and 450 foot-pounds of torque, use a 600 foot-pound capacity torque wrench.

Using A Torque Wrench

1. Torque wrenches can be pulled or pushed. Apply the force steadily.
2. If a seizure occurs while tightening, back off the nut and retighten it with a steady sweep of the handle.
3. Take the torque reading while the wrench is moving.
4. Handle torque wrenches very carefully. If the wrench is dropped check it for accuracy before using it again. Use the following method:
   (a) Hang the torque wrench on a fixed nut as shown in Figure 1-37.
   (b) Set the indicator to "0". (To compensate for the weight of the wrench.)
   (c) Hang a known weight from the wrench handle at any known distance (one or two feet) from the center of the nut.
   (d) The known weight in pounds multiplied by the distance in feet will give you the feet-pounds of torque. This figure should agree with the indicator reading on the wrench. Example shown: 50 lbs. × 2 ft. = 100 feet-pounds. The wrench indicator should read 100 feet-pounds.

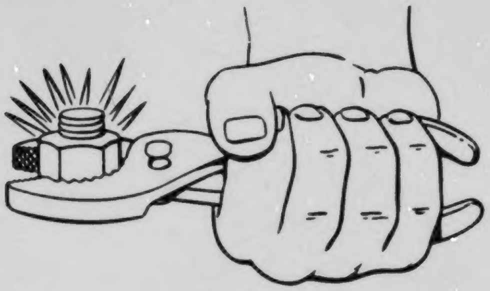
   Remember that any weight or distance can be substituted in the formula, weight times distance equals torque.



(1-37)
CHECKING TORQUE WRENCH FOR ACCURACY
Courtesy of John Deere Ltd.

PLIERS

Combination Pliers: have a slip joint which allows them to open wider. These pliers are intended for holding, twisting, pulling; they should not be used for tightening nuts (Figure 1-38).



X 2271

(1-38)
DON'T USE PLIERS ON NUTS

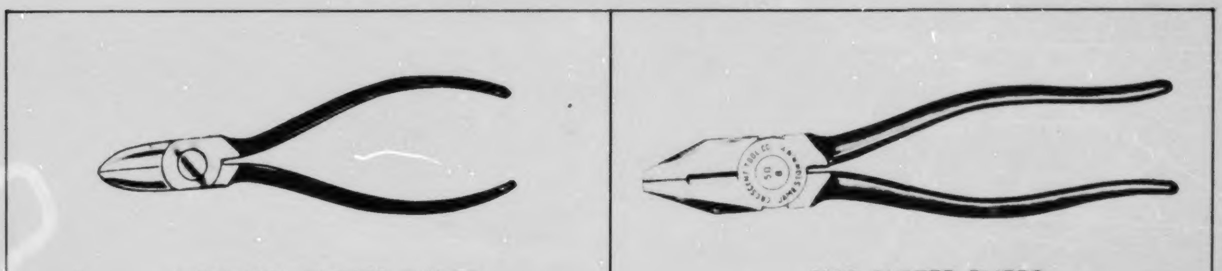
Courtesy of John Deere Ltd.

Diagonal Cutter Pliers: (Figure 1-39) are ideal for pulling cotter pins, especially from slotted nuts. They may also be used for spreading the ends of cotter pins and cutting light gauge wire. Never use diagonal pliers for cutting large-gauge wire.

Side Cutter Pliers: used to cut large gauge wire.

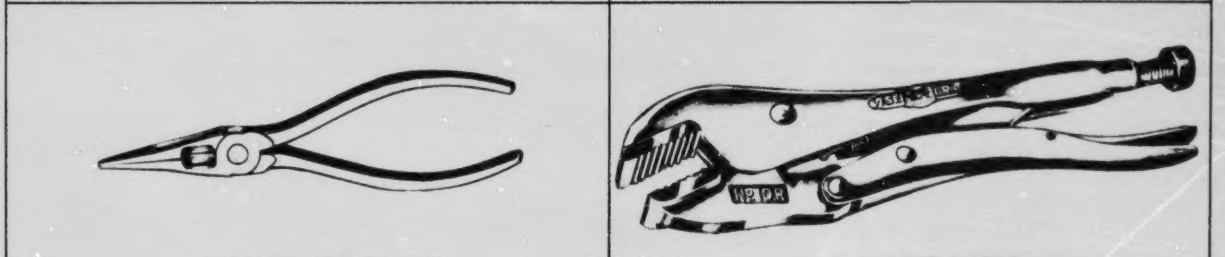
Needle-Nose Pliers: are used primarily for handling small objects and for reaching into restricted areas. Never force them beyond their gripping capacity.

Lock-Grip Pliers (Vise-grips): are specially designed to clamp and hold round and flat objects. One jaw is adjustable to fit different sizes of nuts, bolt heads, pipes, or rods. Never use these pliers on material where you don't want to mar the finish.



DIAGONAL CUTTER PLIERS

SIDE CUTTER PLIERS



NEEDLE-NOSE PLIERS

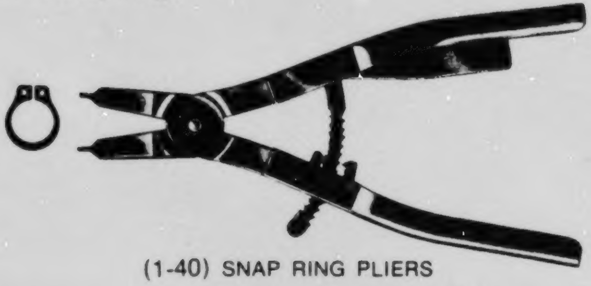
LOCK-GRIP PLIERS

X 2272

(1-39)

Courtesy of John Deere Ltd.

Snap Ring Pliers: Snap rings fit into a bore or casing (internal) or fit on a shaft (external). Snap ring pliers are made to spread or close the rings just enough to allow removal or installation (Figure 1-40). Several types of pliers are available to work with the different types of snap rings.



(1-40) SNAP RING PLIERS

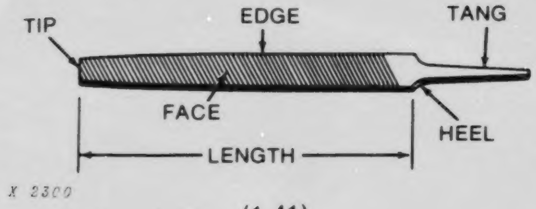
Courtesy of Owatonna Tool Company

Other Types Of Pliers: Following are some special types of pliers: battery (terminal nut) pliers, water pump nut pliers, ignition pliers, hose clamp pliers, brake spring pliers, retaining ring pliers, groove-grip snap ring pliers, horseshoe lock ring pliers, and slip-joint (channel) pliers.

FILES

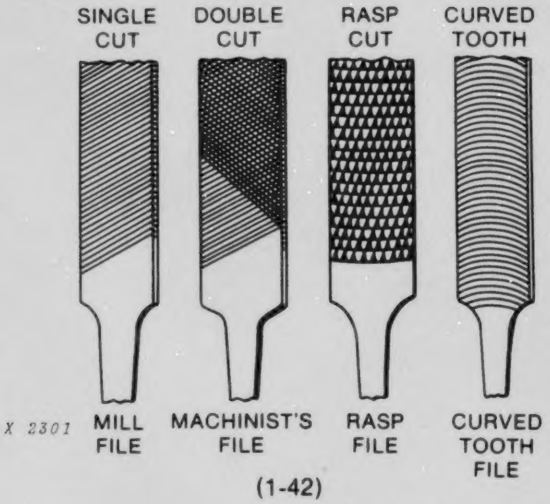
Three important factors in identifying files are: length, type and cut. Length is measured from tip to heel (Figure 1-41), type refers to shape or style, and cut refers to the kind and coarseness of the teeth.

Four common types of cuts of files are shown in Figure 1-42. Mill files are generally used for tool sharpening and removing sharp edges and burrs from cut and worn parts. Machinist's files are used for filing and finishing machine parts. Rasp files are used for cutting wood and very soft metals. Curved tooth files are used on aluminum and steel sheets.



(1-41)

Courtesy of John Deere Ltd.



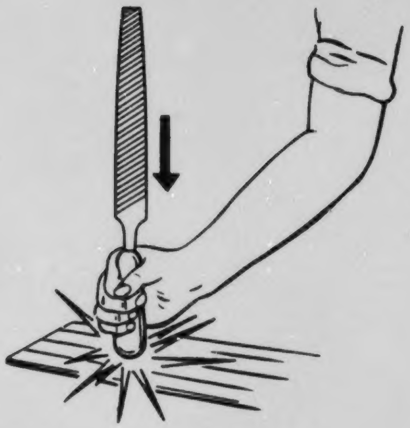
(1-42)

Courtesy of John Deere Ltd.

Correct Use

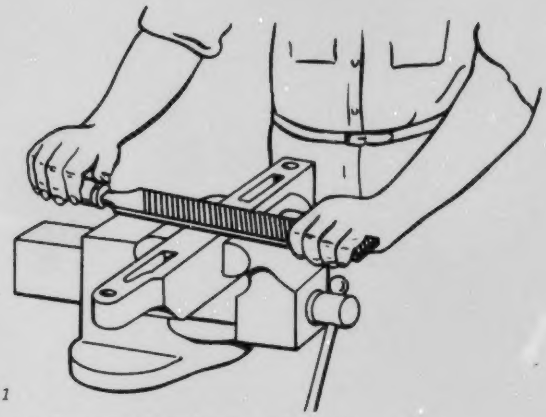
1. Put handles on files: don't use them without handles. Tighten handles as shown in (Figure 1-43)
2. Cut only on the forward stroke. Apply only enough pressure to keep the file moving. Lift the file on the return stroke.
3. Get into the habit of tapping the file at the end of a stroke to clear the teeth of chips.
4. Don't use a file when it is full of chips. Clean it with a file card (Figure 1-43).

   A file card is a brush with short, stiff wire bristles. If chips are left after using the file card, they should be lifted out with a pointed or flattened cleaning wire called a "scorer" which is included with most file cards.
5. The terms rough, smooth, and dead smooth are used to indicate file finishes.
6. Keep oil away from files: it inhibits their cutting ability.
7. Draw-filing is the stroke used to finish flat surfaces such as a gasket surface. To draw-file, take a machinist's file (Figure 1-43) and draw the file crossways over the surface with light pressure (Figure 1-43).
8. To keep files sharp, protect their surfaces when not in use. Do not throw files around on the bench or into a drawer. Keep files away from water to prevent rusting.



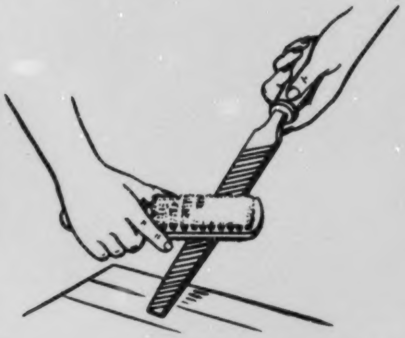
X 2302

(1-43) TIGHTENING FILE HANDLE



X4211

(1-43) CORRECT METHOD OF DRAW-FILING



X 2304

FILE CARD

(1-43) CORRECT USE OF FILES

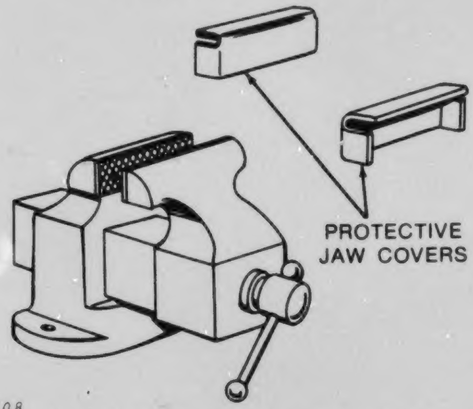
Courtesy of John Deere Ltd.

VISES

The size of a vise refers to the measurement across the jaws. Four to six inch vises are commonly found in heavy duty shops.

Correct Use

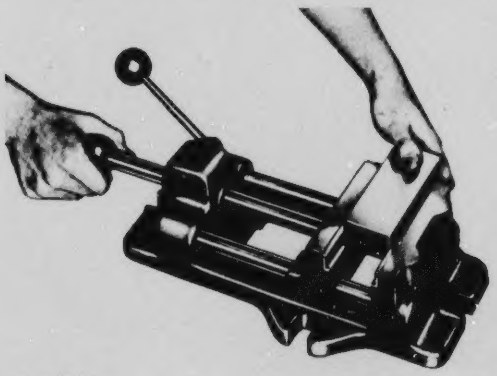
1. Never use a hammer to tighten or loosen a vise; arm strength is sufficient.
2. Always use a vise big enough for the part or type of work to be held.
3. When round parts must be held, soft metal or hardwood jaws can be used to prevent slipping or damage to parts. Whenever finished surfaces must be held, be sure to use soft metal jaw covers as shown in Figure 1-44 so that the finish isn't marred.
4. Use a drill press vise (Figure 1-45) when drilling small pieces of metal.



X 2308

(1-44) MACHINIST'S BENCH VISE

Courtesy of John Deere Ltd.



X 2309

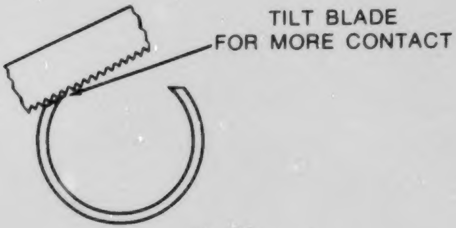
(1-45) DRILL PRESS VISE

Courtesy of John Deere Ltd.

HACKSAWS

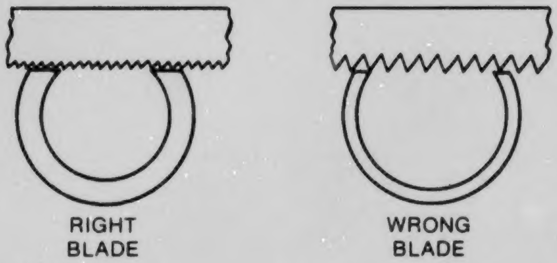
Use And Care

1. Hacksaws can be adjusted to accept different length blades. A properly stretched blade will vibrate with a clear humming sound when plucked.
2. The teeth on a blade must point towards the front of the hacksaw frame.
3. Blades are made with 14, 18, 24 and 32 teeth per inch. The rule of thumb for selecting the correct blade is that two teeth should always be contacting the material when cutting (Figure 1-46).
4. Apply cutting pressure only on the forward stroke. Relieve the pressure on the return stroke (Figure 1-46).
5. For efficient cutting of average metal, work the blade at 40 to 50 strokes a minute. Reduce this rate for harder metals. There is a limit to the hardness of metal that can be sawed with a hacksaw.
6. When cutting very thin material, such as tubing, shift the angle of the saw blade as cutting progresses to allow as many teeth as possible to contact the work at one time (Figure 1-46).
7. Except when starting, use the full length of the blade on every stroke.
8. Usually hacksaw blades are not sharpened; they are thrown away when dull.
9. Wipe the blade occasionally with an oily cloth to keep it from rusting. Also, keep the blade away from other tools to eliminate the possiblity of teeth being broken or dulled.



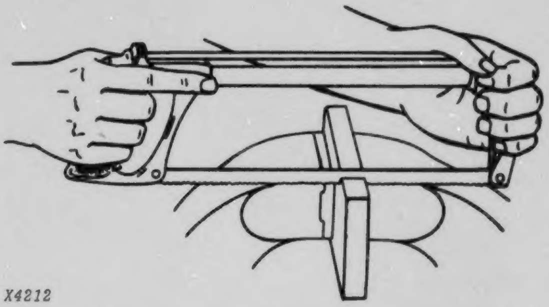
(1-46)
SAWING THIN TUBING

Courtesy of John Deere Ltd.



(1-46) SELECTING THE CORRECT HACKSAW BLADE

Courtesy of John Deere Ltd.



CORRECT WAY TO USE A HACKSAW

(1-46) HACKSAWING

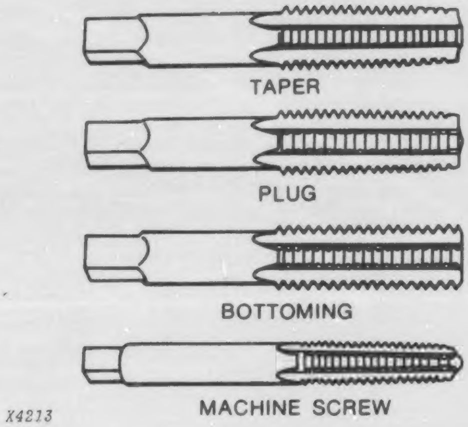
Courtesy of John Deere Ltd.

TAPS AND DIES

Taps

Taps are used for cutting internal threads. There are many styles of taps; common ones are taper, plug, bottoming, and machine screw (Figure 1-47). A taper tap is used to tap completely through the hole; it has a long gradual taper that allows the tap to start easily. A plug tap is used to tap threads partway through. A bottoming tap is used to cut threads all the way to the bottom of a blind hole. A plug tap should precede a bottoming tap, as the bottoming tap will not start well. A machine screw tap is good for small diameter, fine thread jobs. The plug tap is the most widely used tap, and except for running threads completely to the bottom of a blind hole, will cut satisfactory threads for most jobs.

Taps are also made to cut pipe thread. Since pipe thread is tapered (3/4 inch in one foot) only one tap is made for each pipe size.

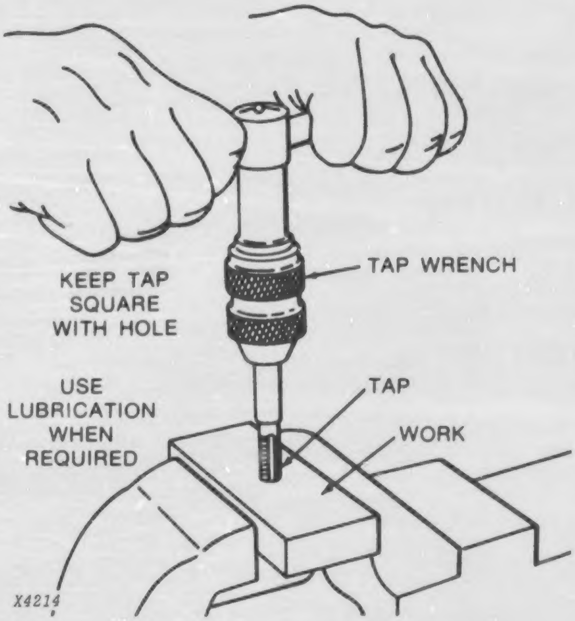


(1-47) FOUR KINDS OF TAPS

Courtesy of John Deere Ltd.

Correct Use Of Taps

After determining the diameter and number of threads per inch of the screw or stud that will enter the tapped hole, use a tap drill-size chart to find what size hole to drill. For example, a 3/8 inch coarse thread stud requires a 5/16 inch hole. Place the tap in a tap handle, and carefully start the tap in the hole (Figure 1-48). Lubricate the tap with cutting oil. After threading the tap one or two turns, back it up a quarter to one-half turn to break the chip. Repeat this process as you continue tapping. Be careful the hole does not clog with chips and cause the tap to break. It may be necessary to withdraw the tap and remove the chips. Taps are quite brittle: use them with care. If they break off in the hole they are difficult to remove.



(1-48) USING THE TAP TO THREAD A DRILLED HOLE

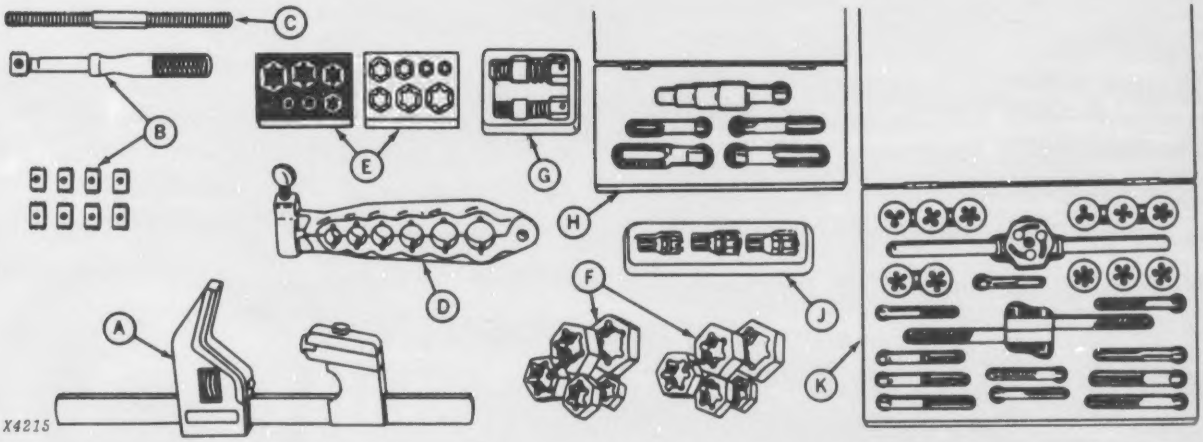
Courtesy of John Deere Ltd.

Dies

Dies are used to cut external threads. A die of the correct size is placed in a diestock (handle). The diestock is turned around the rod to cut the threads. The rod end should be beveled to make it easier to start the die. When cutting the threads, use cutting oil, back up the diestock every one or two turns, and keep the die free of chips. Don't force; turn easily.

Dies are often adjustable in size so that you can slightly enlarge or reduce the outside diameter of threads and improve the thread fit.

Special taps and dies are illustrated in Figure 1-49. One form of rethreading the tool is shown in A. It is placed on the thread and turned. B shows an internal thread chaser used to clean up dirty or damaged internal threads. The thread restorer, C, is handy for quickly reconditioning external threads. The axle rethreader, D, is placed around the good thread area, clamped shut, and then turned back over the damaged area. Nut or rethreading dies, E and F, can be turned on a damaged thread. An ordinary box wrench can be used to turn them. G and H are spark plug hole taps. These are very handy to clean up damaged or carboned plug hole threads. A combination tap and die set for tube flare fittings is illustrated in J, and a combination tap and die set in K.



A — Rethreading Tool
B — Internal Thread Chaser
C — Thread Restorer
D — Axle Rethreader
E-F — Rethreading Dies
G-H — Spark Plug Hole Taps
J — Tap and Die Set for Tube Flare Fittings
K — Combination Tap and Die Set

(1-49) TAPS AND DIES

Courtesy of John Deere Ltd.

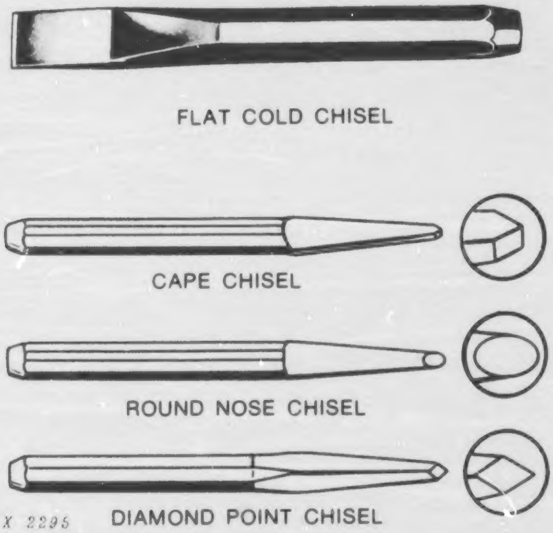
CHISELS

Flat Cold Chisel (Figure 1-50): the most common chisel used by the servicemen. They are used for cutting metal. Common uses of chisels for a mechanic are to break rivets and split nuts.

Cape Chisel: used for cutting keyways, narrow grooves, and square corners.

Round Nose Chisel: used for cutting semicircular grooves and chipping inside corners which have a fillet or radius.

Diamond Point Chisel: used for cutting V-grooves and square corners.


FLAT COLD CHISEL
CAPE CHISEL
ROUND NOSE CHISEL
X 2295
DIAMOND POINT CHISEL

(1-50) CHISELS

Courtesy of John Deere Ltd.

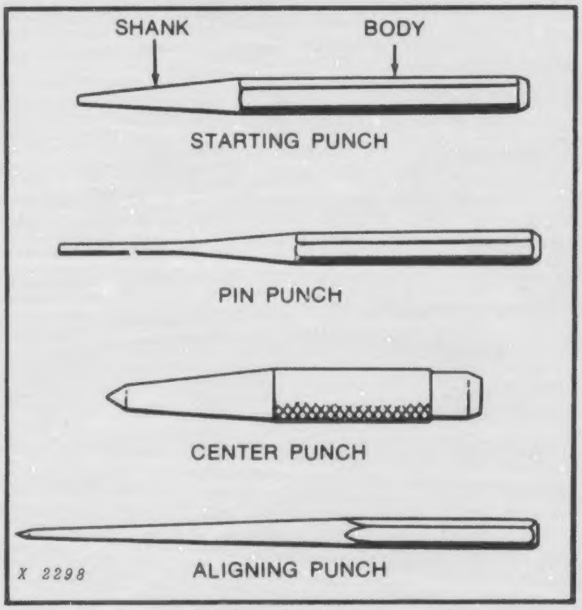
PUNCHES

Starting Punch (Figure 1-151): used to knock out rivets and to start or knock out straight or tapered pins.

Pin Punch: used for driving out pins after the starting punch can no longer be used. Don't use a pin punch to start a pin moving: the slim shank could bend or break.

Center Punch: used to mark the center of a hole that is to be drilled. The mark ensures that the drill will bite in the right spot and won't wander.

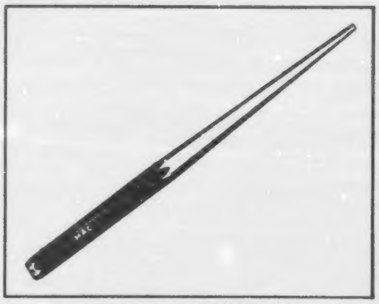
Aligning Punch: used to shift parts to line up corresponding holes. Never use an aligning punch as a center punch.


SHANK
BODY
STARTING PUNCH
PIN PUNCH
CENTER PUNCH
X 2298
ALIGNING PUNCH

(1-51) PUNCHES

Courtesy of John Deere Ltd.

Drift Punches (Figure 1-52): are long punches usually between one and two feet in length; they are used for reaching hard-to-get-at spots and for lining up. Some drifts are tapered, while others such as a brass drift are a straight rod (Figure 1-53).

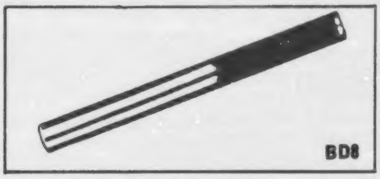


DRIFT PUNCHES

Tool No.	Point Size	Length	Stock Size
DP5	5/32"	8"	3/8"
DP6	3/16"	9"	1/2"
DP8	1/4"	12"	5/8"
DP10	5/16"	11"	5/8"
DP12A	3/8"	16"	3/4"

(1-52)

Courtesy of Mac Tools



BRASS DRIFT

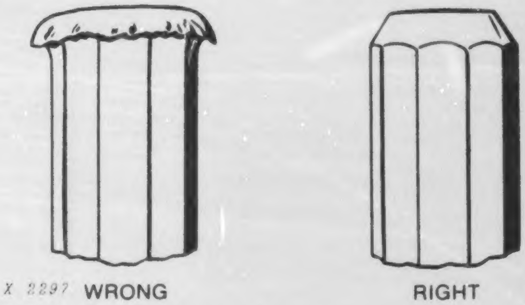
To get at driving jobs where a soft punch is required. 8" long, 3/4" stock.

(1-53)

Courtesy of Mac Tools

Correct Use Of Chisels And Punches

1. A chisel (or punch) should be held fairly loose, so that the jarring vibrations are not all transmitted to the hand. Also, the hand is less likely to get injured in case of a miss.
2. Wear safety glasses when using a chisel.
3. A chisel will cut any metal softer than itself. Always use a chisel that is big enough for the job and a hammer that is heavy enough for the size of the chisel. This also applies to punches.
4. When grinding a chisel or punch never hold it against the grinding wheel too long. Dip it frequently in water or coolant to keep it cool. Otherwise it will lose its temper and become soft.
5. The end of chisels and punches will tend to flair out after repeated blows from a hammer. Keep the head ground back as shown in Figure 1-54.



(1-54)

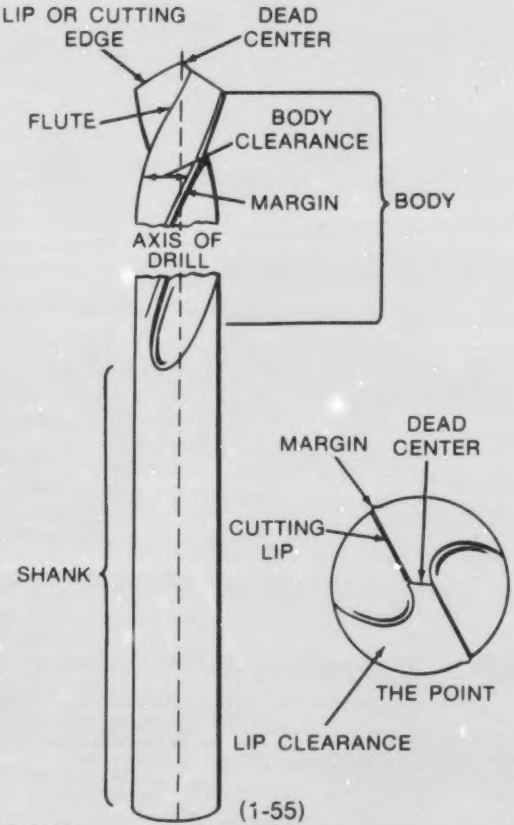
GRIND BACK CHISEL AND PUNCH HEADS

Courtesy of John Deere Ltd.

TWIST DRILLS

Twist drills are made of either carbon tool steel or high-speed tool steel. Carbon steel will lose its temper if excessively heated and allowed to cool, whereas high-speed steel can become red hot and then cool and still not lose its temper. Twist drill terminology is shown in Figure 1-55.

Twist drills have four classifications: fractional drills rise in size from 1/64" by 64ths up to 1" and larger; number drills rise in size from No. 80 to No. 1, with diameters measuring from .0135 inches to .228 inches; letter drills range in size from A to Z, with diameters from .234 inches to .413 inches; metric drills are generally listed from 1 mm upwards in .5 mm increments.



(1-55)
TWIST DRILL
Courtesy of John Deere Ltd.

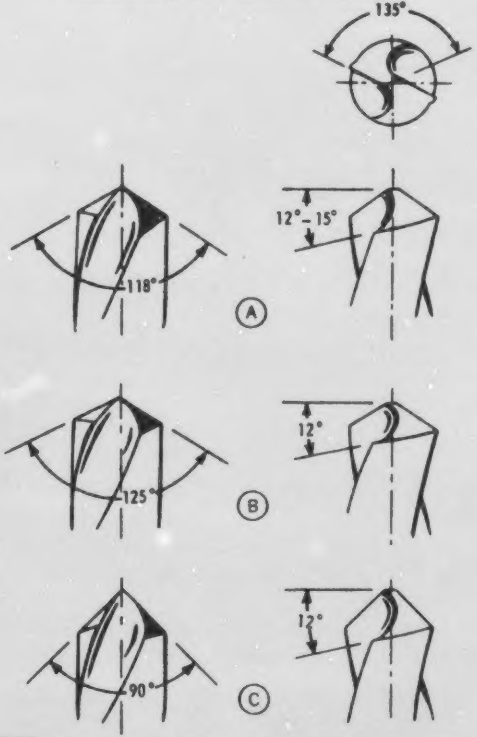
Sharpening Drills

To drill accurately drills must be sharp. Drills are sharpened by grinding them either freehand or with a jig that attaches to a grinder. It is important that drills be ground accurately; for example, if the length of the cutting edges are unequal from grinding, the hole will be larger than the diameter of the drill.

Figure 1-56 illustrates the most commonly used drill shapes. The lips do the cutting and therefore must be ground to a sharp edge. These lips or cutting edges must be of uniform length. The portion behind the lips is ground down on an angle to provide lip clearance.

For steel and cast iron, cutting edges are ground on a 59 degree angle to the drill axis or 118 degrees included angle as shown in "A". Note that the lip clearance angle on "A" is 12 degrees to 15 degrees. "B" illustrates a drill ground to drill heat-treated steels and drop forgings. Note that the included angle is greater and the lip clearance angle is 12 degrees. When drilling softer material such as wood, hard rubber, fiber, or soft cast iron, a much smaller included angle can be used as shown in "C". When any unusual material such as spring steel must be drilled, consult a machinist's handbook to obtain the correct angles and shapes.

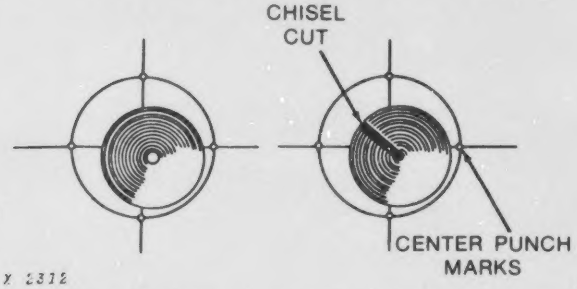
Note: Always be sure to keep drills cool while grinding by dipping them occasionally in water or oil.



(1-56) COMMON SHAPE OF DRILLS
Courtesy of John Deere Ltd.

Correct Use

1. For low speed drilling, carbon tool steel drills can be used.
2. For high-speed drilling, use drills of high-speed tool steel.
3. Always center punch before drilling.
4. After the drill has enlarged the center punch mark slightly and before the whole point has entered the material, check to see that the hole is correctly centered. If the drill is not entering the right spot, it can be drawn over by making a chisel cut on the side to which the drill should be drawn (Figure 1-57).
5. Always use a lubricant to cool the drill.

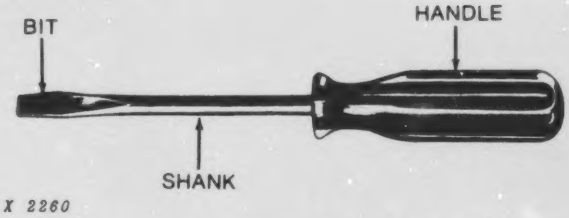


(1-57) HOW TO DRAW THE DRILL BACK TO CORRECT CENTER
Courtesy of John Deere Ltd.

6. In work where extreme accuracy is specified drill the hole just under the finished size. Follow the drill with a boring tool to correct any eccentricity and then bring the hole to the exact diameter with a straight reamer.
7. Note that as the diameter of the drill increases the recommended speeds decrease proportionally, also that as the rate of feed is increased the recommended speeds increase more or less proportionally.

SCREWDRIVERS

Common Screwdriver: one of the most frequently used tools by a mechanic. It is made for straight slot screws and comes in various shank lengths and thicknesses and bit widths and thicknesses (Figure 1-58A).



(1-58A) COMMON SCREWDRIVER
Courtesy of John Deere Ltd.

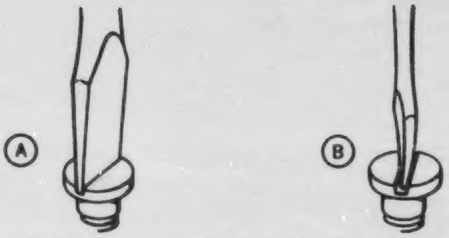
Phillips-Head Screwdriver (Figure 1-60): will not slip sideways out of the cross slots of a Phillips-head screw, but more force must be exerted in keeping it in the slots. If the bit gets damaged, it is not practical to repair it.

Clutch-Head Screwdriver: is used with screws for sheet metal and trim where a neat appearance is desired. The tip of the screwdriver is very strong and stays in the screw opening with only moderate pressure.

Offset Screwdriver: used where space is limited and the screw is hard to reach. Bits are normally at right angles to each other, allowing the screw to be turned a quarter turn at a time by using opposite ends alternately. Use the offset screwdriver cautiously as the bit has a tendency to jump out of the slot and chew up the screw head.

Correct Use

1. Never use a common screwdriver as a cold chisel, a punch, or a prying bar. If you must tap on the screwdriver, use one made for tapping.
2. Don't twist the shank of a standard screwdriver with pliers or a wrench. If necessary, use a heavy-duty screwdriver with a square shank made for this purpose.
3. Never use a screwdriver to check an electrical circuit where the amperage is high.
4. A good rule is never put any part of your body in front of a screwdriver bit. It could injure you.
5. Be sure the screwdriver bit fills the slot in the screw head (Figure 1-58B). Too small a bit will twist and chew up the screw.



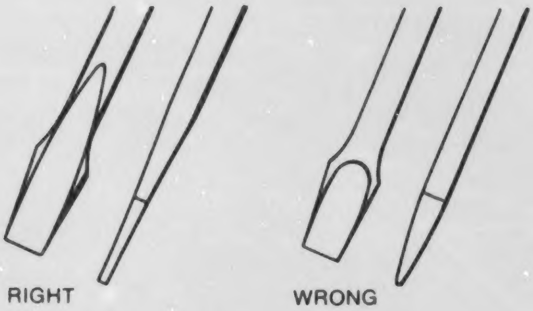
HOW A SCREWDRIVER SHOULD FIT THE SCREW SLOT

POOR FIT DAMAGES SCREWDRIVER AND SCREW SLOT

X 2261

(1-58B) BE SURE THE SCREWDRIVER FITS THE SCREW SLOT
Courtesy of John Deere Ltd.

6. If a screwdriver bit becomes rounded or broken, it can be reground as follows: grind the tip until it is straight and at right angles to the shank (Figure 1-59). The sides should have very little taper and should never come to a sharp point at the tip. Never hold the screwdriver against the grinding wheel for long periods. Dip the bit in water to keep it cool.



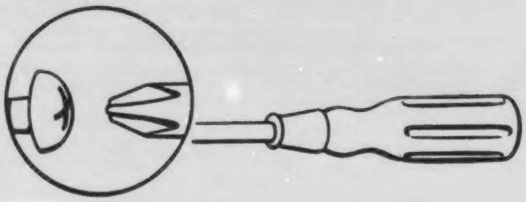
RIGHT

WRONG

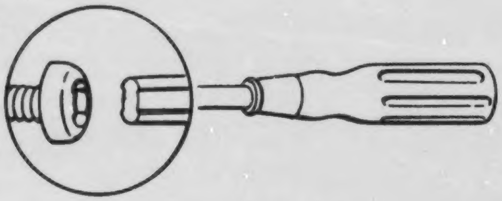
X 2262

(1-59)
GRINDING A SCREWDRIVER BLADE
Courtesy of John Deere Ltd.

Starting Screwdriver: used for removing and installing screws in places difficult to reach with the hand. Once a screw is started, a common screwdriver can often be used to finish the job. Other starting screwdrivers have twisting centers or are magnetized to hold the screws.

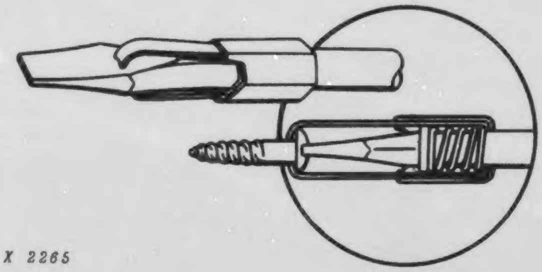


PHILLIPS-HEAD



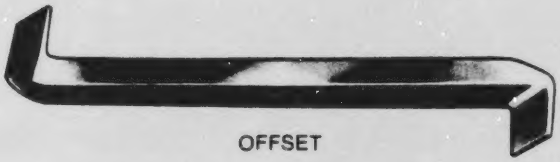
CLUTCH HEAD

X 2263



X 2265

STARTING (SHOWN HOLDING SCREW)



OFFSET

(1-60) SCREWDRIVERS
Courtesy of John Deere Ltd.

SOLDERING TOOLS

Soldering is the process of joining two pieces of metal by using a third metal as an adhesive. Unlike welding, soldering does not involve melting the two metals being joined. Standard solder melts at 800°F., far below the melting point of most metals.

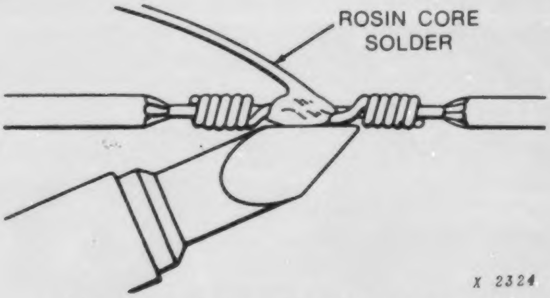
Solder is a mixture of varying combinations of tin and lead. Hard solder contains a high proportion of tin, whereas soft solder has a low proportion of tin. Solder is available in stick and in wire rolls. Some types contain their own flux, while others must be dipped in flux or have flux applied to the joint areas. (Flux is a substance such as borax or rosin that cleans the metal of oxides and helps the solder fuse the two metals together.)

There are three common methods of soldering:

1. Soldering Irons — electric soldering irons come in various sizes ranging from 18 watts for a small pencil iron to 400 watts for a large iron. The area and amount of heat required for a job will decide which size iron is most suitable.
2. Soldering Guns — electric soldering guns are used to solder electrical connections. The trigger switch can be turned on and off as required.
3. Torches — oxyacetylene torch or a propane torch kit can be used to heat metals for soldering. (A propane torch kit has a disposable propane cylinder and soldering tips, as well as other accessories.) Broad areas can be soldered faster with a torch because it supplies more heat. There is a danger with torches, however of overheating the material and of damaging nearby parts such as hoses.

Soldering Procedures

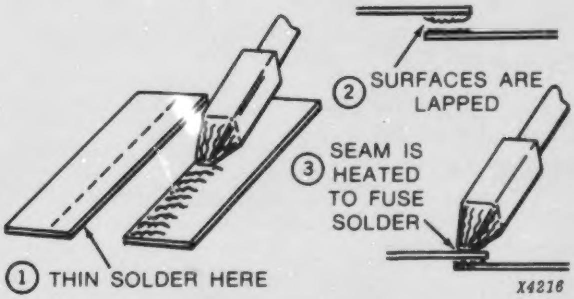
1. Thoroughly clean the work to be soldered, removing all rust scale and oxidation. A quick brush over with a wire brush is not good enough.
2. Before using a soldering iron or tip, it must be tinned. To tin an iron, heat it and apply solder to it.
3. Heat the pieces to be soldered and apply flux if it isn't included in the solder.
4. Always apply solder to the work, not to the iron.
5. Soldering a copper wire connection is illustrated in Figure 1-61. Remove heat after the solder has thoroughly penetrated the joint, and hold the two pieces rigid until the solder cools and sets. Always use rosin core solder when doing electrical work.



(1-61) SOLDERING COPPER WIRES

Courtesy of John Deere Ltd.

6. Soldering a lap joint is illustrated in Figure 1-62.



(1-62) SOLDERING COPPER WIRES

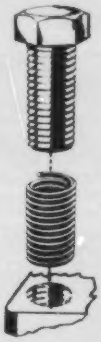
Courtesy of John Deere Ltd.

Soldering Hints

1. Keep soldering irons or tips smooth by filing them.
2. Excessive solder can be removed from a tip with a cloth when the iron is hot.
3. Don't let irons overheat: turn them off when not in use.
4. Metal is ready for soldering when the solder melts freely and sizzles.
5. When using a propane torch kit for soldering in an area where nearby parts could be damaged, heat the tip and then turn the propane off before using the tip.

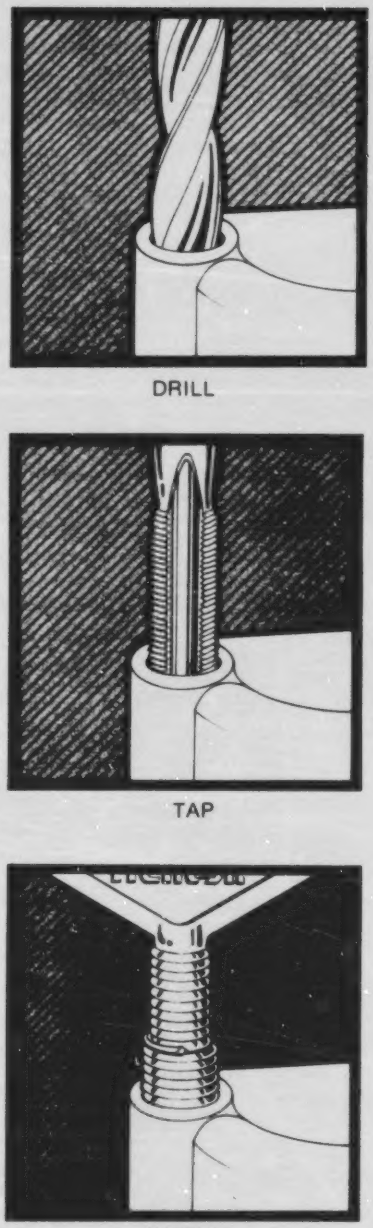
THREAD RESTORER KIT

When threads in castings or other expensive parts are damaged or completely stripped, they can be repaired with a thread restorer. Helicoil thread restores (Figure 1-63) are the most common type. A basic Helicoil kit contains a Helicoil insert of a certain size and a corresponding tap and Helicoil installation tool. More complete kits are available that contain various sizes of Helicoil inserts, taps, and winding tools. Procedures to install a Helicoi are as follows (Figure 1-64).



(1-63)
Courtesy of Helicoil Products

1. Drill out damaged or stripped threads using the drill size specified in the Helicoil kit. Drill to an adequate depth — right through, or for blind holes, to the bottom.
2. Using the tap supplied with the kit, cut the threads that will receive the insert.
3. Taking the installation tool supplied (Figure 1-65), screw the helicoil insert on the tool. The insert should be screwed far enough so that the tang (Figure 1-66) is engaged in the slot at the bottom of the tool. Now screw the insert into the tapped hole until it is one-quarter to one-half turn below the surface of the hole.
4. Finally the tang must be removed. Place the square end of a punch (no bevel) on the tang and strike it sharply with a hammer. The tang will break off at the notch.



DRILL

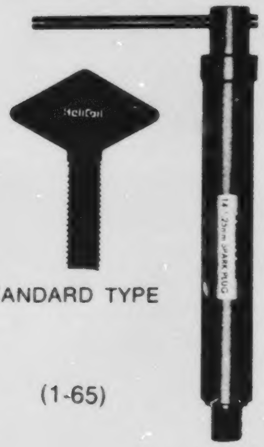
TAP

INSTALL

(1-64) INSTALLING A HELICOIL
Courtesy of Helicoil Products

Once installed, Helicoil inserts stay in place for this reason: in their free state the inserts are larger than the taped hole (Figure 1-67). Thus when they are installed they are compressed, and the spring action of compression presses them against the sides of the tapped hole, holding them in place.

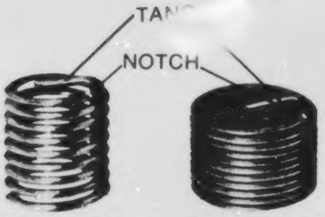
HELI-COIL INSTALLATION TOOLS



(1-65)

Courtesy of Helicoil Products

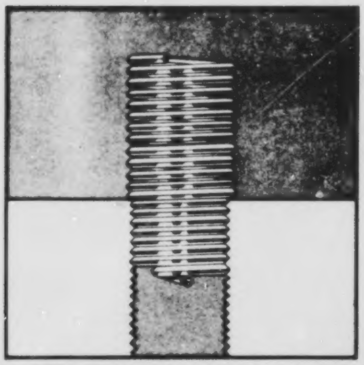
HELICOIL STAINLESS STEEL INSERTS



STANDARD SPARK PLUG

(1-66)

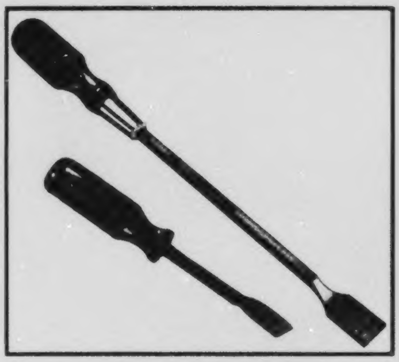
Courtesy Of Helicoil Products



(1-67) HEILI-COIL INSTALLATION
Courtesy of Helicoil Products

BRUSHES AND SCRAPERS

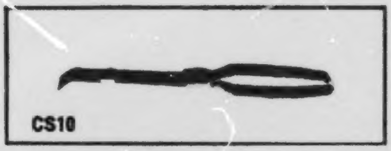
Brushes and scrapers are used for cleaning jobs, for removing dirt, grease, carbon buildup, rust, scale and paint from parts and equipment. Some types of scrapers likely to be found in a repair shop are illustrated in Figure 1-68. The illustrations are taken from a tool catalogue. Common types of brushes are shown in Figure 1-69, and specialty brushes in Figure 1-70.



CARBON SCRAPERS
long blade

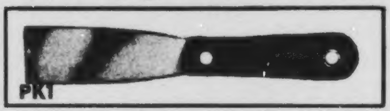
Tool No.	Type Handle	Length
S16	Wood Handle	11¾"
SP16	Plastic Handle	11¾"
SP8	Plastic Handle	8"

(1-68) SCRAPERS
Courtesy of Mac Tools



FLEXIBLE WIRE CARBON SCRAPER

CS10 — 10" long, 1" wide.



STANDARD PUTTY KNIFE

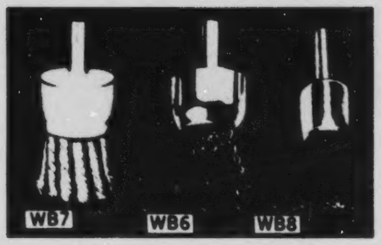
PK1 — 1⅜" blade.

PK2 — Heavy-duty, Thick Stiff Blade — 1⅜".

PK10 — Heavy-duty, Thick, Stiff Blade — 3".

PK12A — Standard-duty, Flexible Blade — 3".

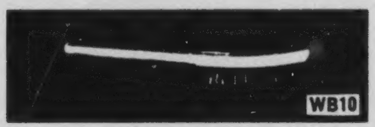
Courtesy of Mac Tools



HEAVY-DUTY CARBON CLEANING BRUSH

WB8 — End Brush. ½" diameter with ¼" shank.
WB6 — Similar to the WB8. 1" in diameter. ¼" shank.
WB7 — Cable Twist 1" diameter with ¼" shank.

NYLON BRISTLE MOTOR CLEANING BRUSH

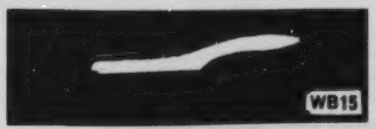


HAND WIRE BRUSH

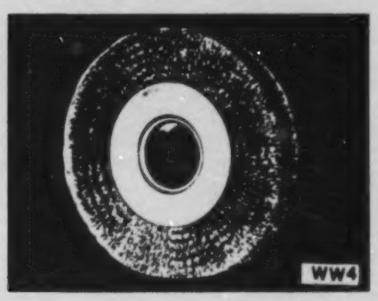
WB10 — Length 14".

ADAPTOR FOR DRILL CHUCK

CA1 — ¼" shank.
CA2 — Adaptor for Drill Chuck. ⅜" shank.
CA3 — Adaptor for Drill Chuck. ½" shank.



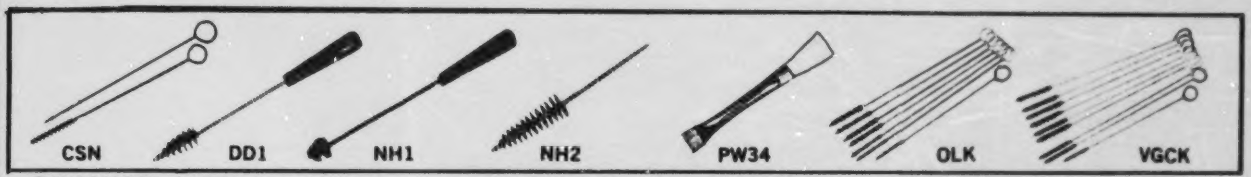
SHOE HANDLE WIRE BRUSH



STANDARD WIRE WHEEL BRUSH

(1-69) COMMON BRUSHES

Courtesy of Mac Tools



CRANKSHAFT OIL HOLE BRUSH SET

CSN — Set of two Tynex nylon brushes 5/16 and 7/32 x 2 x 10.

DETROIT DIESEL BRUSH

DD1 — Stainless steel bristle with handle to be used when changing injector while in truck.

CUMMINS DIESEL BRUSH

NH1 — Stainless steel bristle — handle to be used when changing injector while in truck.

CUMMINS DIESEL BRUSH

NH2 — Stainless steel bristle — cut for power, cleans or polishes entire copper. Best used as a bench tool

3/4" PARTS WASH BRUSH

PW34 — Aluminum handle — economy size — polypropylene.

NYLON OIL LINE BRUSH KIT

OLK — Tynex nylon brushes for: feed line, block oil return lines, overhead rocker feed lines, valve guides, cam and crankshaft.

VALVE GUIDE BRUSH SET

VGCK — Set includes sizes ¼, 5/16, 11/32, ⅜, 13/32, 7/16, and ½.

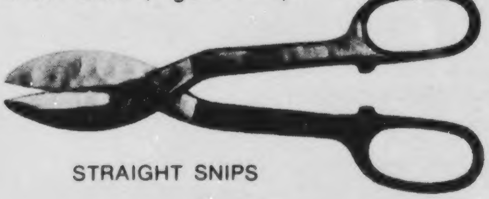
(1-70) SPECIALTY BRUSHES

Courtesy of Mac Tools

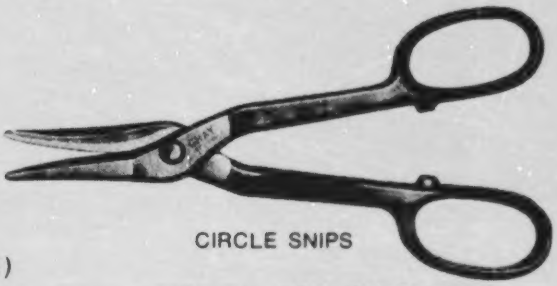
SNIPS

Snips are used for cutting sheet metal and other sheet material like that used for gaskets. In a repair shop snips are used for such jobs as cutting shim stock, sheet metal for small fabrication jobs, and gasket material.

Both straight cutting and circle cutting snips are available (Figure 1-71).



STRAIGHT SNIPS



CIRCLE SNIPS

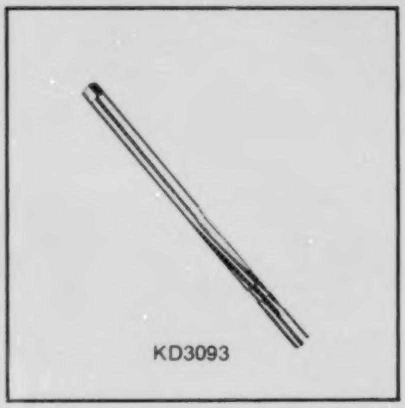
(1-71)

Courtesy of Gray Tool Company

REAMERS

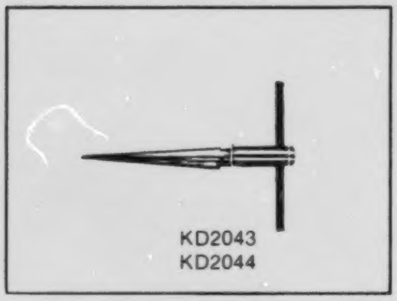
Reamers (Figure 1-72) are used for cleaning, enlarging, shaping holes. Some uses for reamers in the heavy duty shops are removing burrs, aligning holes in sheet metal, starting taps, and resizing holes when new bushings are installed.

Reamers are available singly in fixed and adjustable sizes or in sets; they can be turned by hand in a tap wrench or be put into an electric drill. Adjustable reamers are usually turned by hand. Note that reamers must never be turned anticlockwise in a hole as they may jam and the cutting blades could break. Always turn reamers clockwise.



STRAIGHT
REAMER

Courtesy of Mac Tools



REPAIRMAN'S REAMERS

KD2043— Reamer—Range ⅛" to ½".
KD2044 — Reamer— Range 7/16" to 1".

(1-72) REAMERS

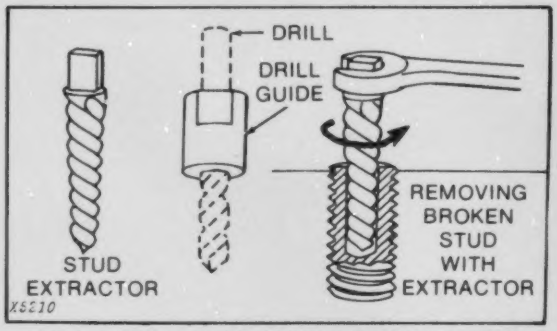
Courtesy of Mac Tools

Screw Extractors

When a stud, pipefitting or nipple breaks off below the surface, a stud extractor is needed to remove it. Several types are available, the most common known as an "Ezy Out". It is a hardened tapered rod with coarse, sharp, left-handed spirals. It has a square on top, it is for turning the extractor with a wrench. To use the extractor, a hole is drilled in the exact center of the stud. This must be done carefully as most studs are hard and difficult to drill. Some extractor kits are available with guides (Figure 1-73) that center the drill in the hole and keep it straight. If a guide isn't available, a small pilot hole drilled first will help. Turn the extractor into the hole, apply a firm pressure on the wrench and back out the stud. This must be done carefully, as it is easy to break off the extractor in the hole further complicating the problem.

At times you will find broken studs and pipefittings so tight an extractor can't remove them. In this case drill out the piece close to its threads, then tap the hole with the correct sized tap.

Getting out broken studs and fittings is an art learned through practice. Observe the tricks and techniques of experienced mechanics doing the job. For example, one trick you might see is heating the stud or surrounding casting with a torch, then quenching the stud. This will sometimes shrink the stud enough so it can be removed with an extractor. The point to remember about removing broken studs or fittings is that they broke off because the threads were extremely tight or frozen in the first place and so they will probably be difficult to get out.



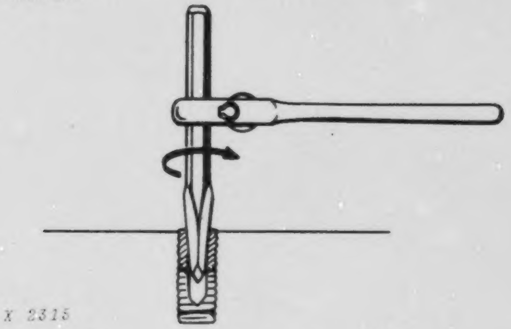
EXTRACTOR FOR REMOVING BROKEN STUDS

(1-73)

Courtesy of John Deere Ltd.

Extractor sets contain extractors in several sizes, guides in several sizes to center the drill, and other useful stud extracting items.

In an emergency, a diamond-point chisel sometimes can be used to remove a broken stud (Figure 1-74). Drive the chisel into the stud after drilling a small hole in the center of the stud. Then turn the chisel carefully with a wrench.

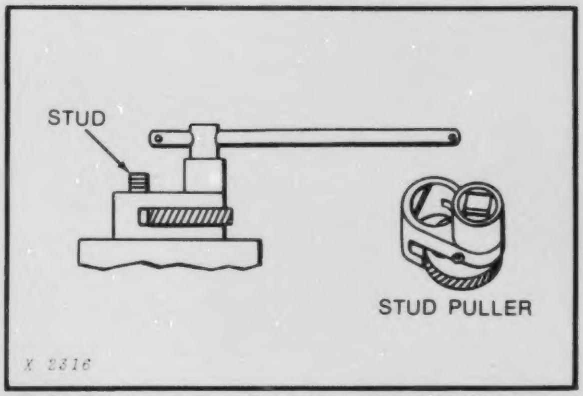


(1-74) USING CHISEL AS EMERGENCY STUD REMOVER

Courtesy of John Deere Ltd.

STUD PULLER

To remove unbroken studs, use a stud puller. Drop the stud puller over the stud to be removed (Figure 1-75). Use a "T" or flex handle to turn the stud out. The puller automatically grips the stud with a knurled eccentric as pressure is applied. One size fits almost all studs. In all stud removals, use a generous amount of penetrating oil.

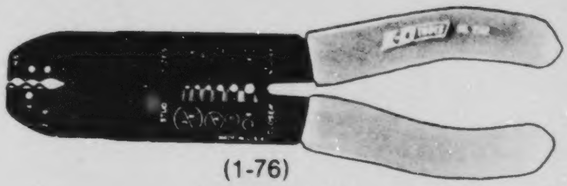


(1-75) STUD PULLER FOR UNBROKEN STUDS

Courtesy of John Deere Ltd.

WIRE SPLICERS

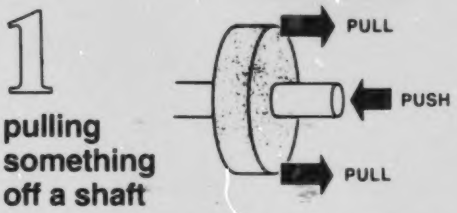
Wire splicer (Figure 1-76) are special pliers made for use with electrical wiring; they strip insulation from wire, cut wire, and crimp ends to wire.



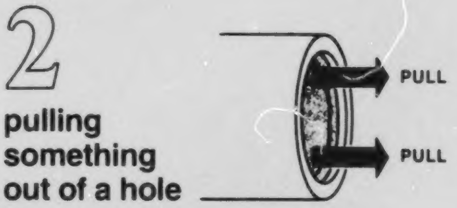
(1-76)
WIRE SPLICER

PULLERS

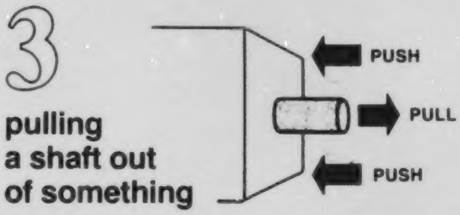
Three basic pulling problems are illustrated in Figure 1-77. The solutions to these problems are shown in Figures 1-78, 1-79 and 1-80. Examples of pulling jobs are shown in Figure 1-81.



Removing a gear, bearing, wheel, pulley, etc., to replace it or get at another part.



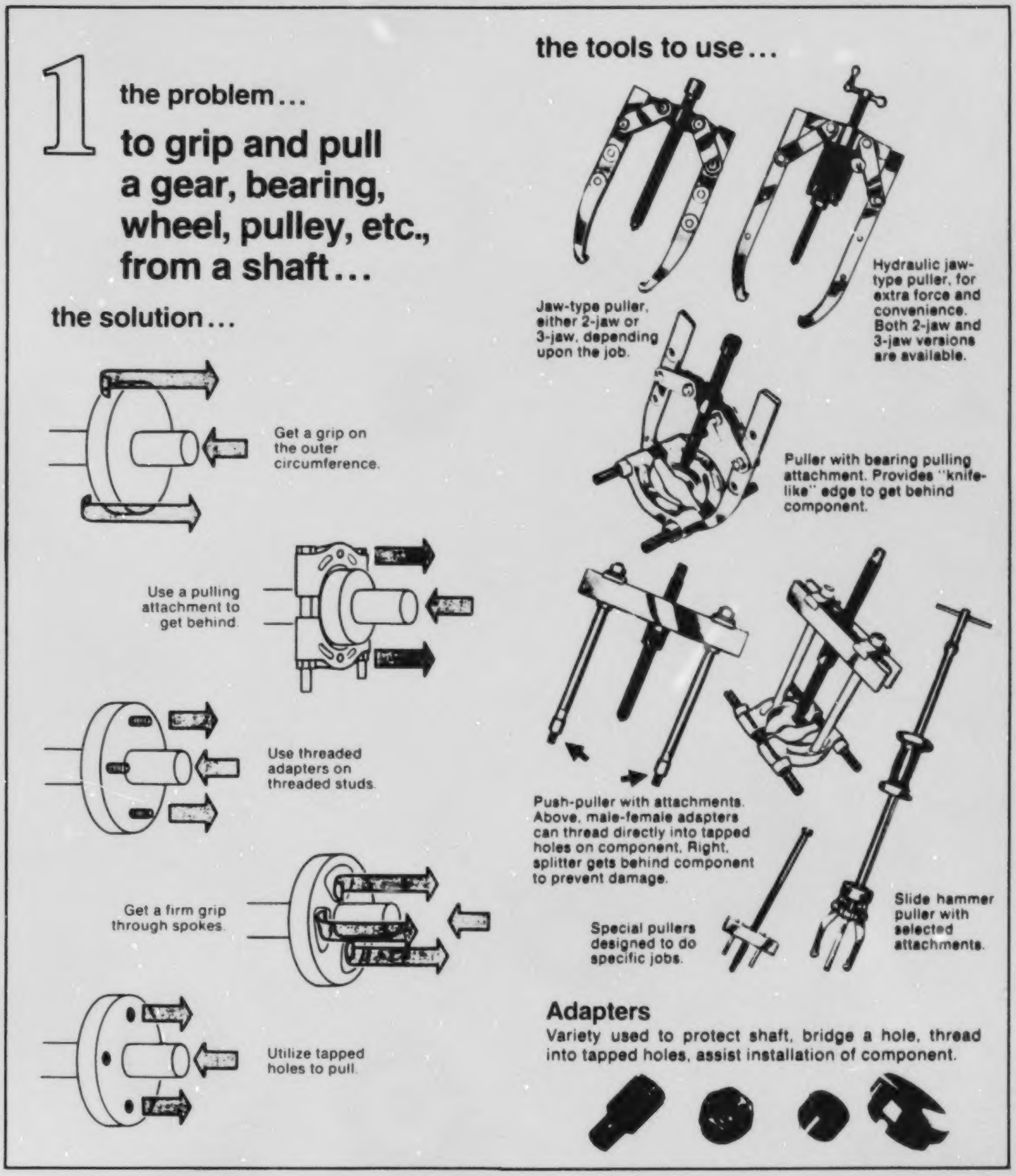
Internal bearing cups, retainers or oil seals are usually press-fitted and are difficult to remove.



A transmission shaft or pinion shaft is often hard to remove from a bore or housing.

(1-77) BASIC PULLING PROBLEMS

Courtesy of Owatonna Tool Company



1 the problem...

to grip and pull a gear, bearing, wheel, pulley, etc., from a shaft...

the solution...

Get a grip on the outer circumference.

Use a pulling attachment to get behind.

Use threaded adapters on threaded studs.

Get a firm grip through spokes.

Utilize tapped holes to pull.

the tools to use...

Jaw-type puller, either 2-jaw or 3-jaw, depending upon the job.

Hydraulic jaw-type puller, for extra force and convenience. Both 2-jaw and 3-jaw versions are available.

Puller with bearing pulling attachment. Provides "knife-like" edge to get behind component.

Push-puller with attachments. Above, male-female adapters can thread directly into tapped holes on component. Right, splitter gets behind component to prevent damage.

Special pullers designed to do specific jobs.

Slide hammer puller with selected attachments.

Adapters

Variety used to protect shaft, bridge a hole, thread into tapped holes, assist installation of component.

(1-78) PULLING FROM A SHAFT

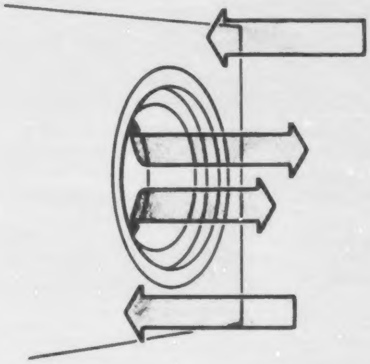
Courtesy of Owatonna Tool Company

2

the problem…

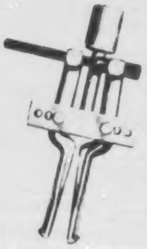
to grip and pull an internal bearing race, retainer, oil seal, etc.…

the solution…

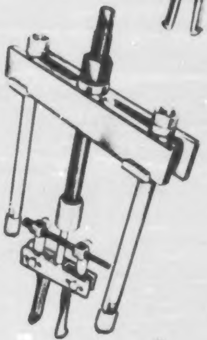


While parts within a "blind hole" in a housing do present a challenge, there are pullers to solve it. By extending the narrow jaws of an internal pulling attachment through the center of the part to be pulled, a straight pull is assured, and damage to the housing is avoided.

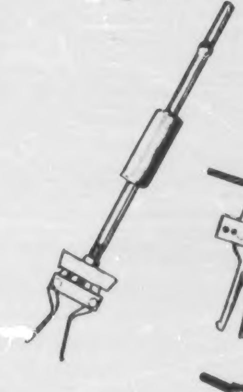
the tools to use…

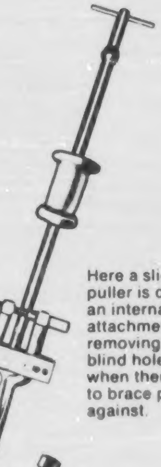


Designed for use with Push-pullers or slide hammer pullers, internal pulling attachments provide a straight pull, prevent damage to housings. Various sizes are offered.

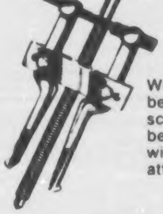


Push-puller in combination with internal pulling attachment. Both mechanical and hydraulically-powered versions are available.





Here a slide hammer puller is combined with an internal pulling attachment. Ideal for removing parts from blind holes, especially when there is no housing to brace puller legs against.



When there is a shaft to bear against, a forcing screw of proper size may be used in combination with an internal pulling attachment.

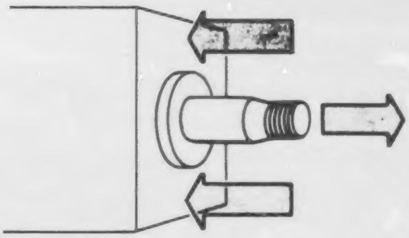
(1-79) PULLING FROM A HOLE

Courtesy of Owatonna Tool Company

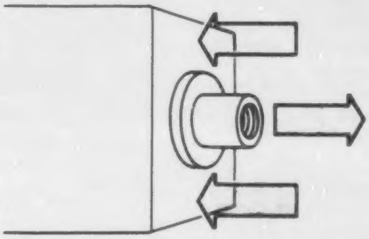
3 the problem...

to grip and pull a press-fit shaft from a housing...

the solution...



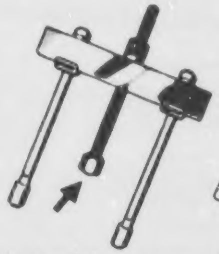
You can "get a hold" on the shaft if its end is threaded.



Or, use a male-female adapter to engage a tapped hole in the end of the shaft.

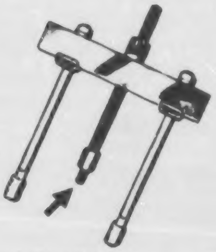
Sometimes, we can push a shaft through a housing, rather than pulling it out. In applications of this type, the puller legs must be securely fastened to the housing and the screw may simply bear against the shaft.

the tools to use...

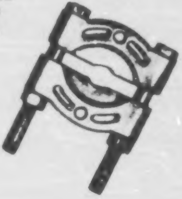


Push-puller with threaded adapter. Use a mechanical or hydraulic puller, depending on the size of the shaft to be pulled.

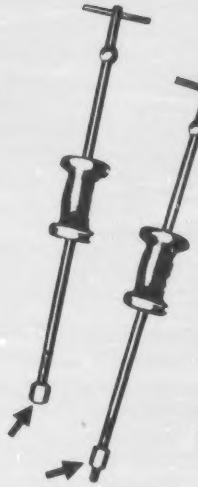
Female threaded adapter allows you to thread onto shaft directly for pull.



Male-female threaded adapter threads into tapped hole of shaft for direct pull.



When the housing lacks sufficient surface for the puller legs to bear against, a pulling attachment (shown above) may be used to provide support.



Slide hammer puller with threaded adapter—either male-female or female.

ADAPTERS

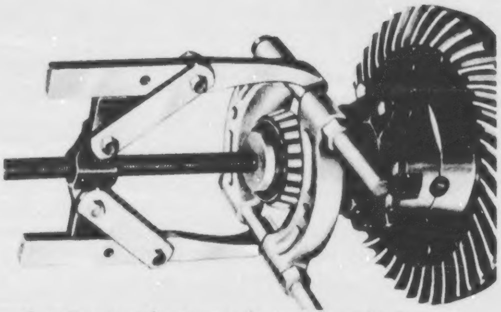
FEMALE ADAPTERS
Fasten to the male threaded end of shaft to pull while pushing against the housing.

MALE-FEMALE ADAPTERS
Thread into shaft to pull shaft while pushing against the housing.

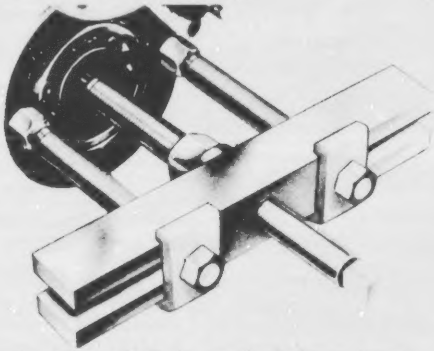
(1-80) PULLING OUT A SHAFT

Courtesy of Owatonna Tool Company

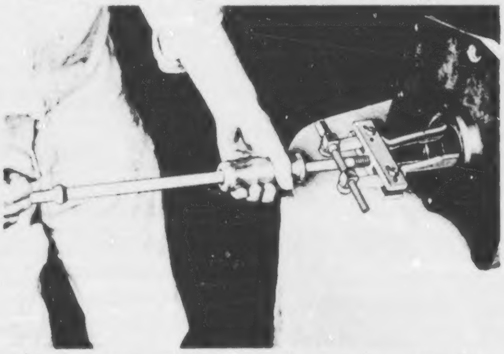
EXAMPLES OF PULLING JOBS



A roller bearing cone is removed by jaw-type puller. "Knife-like" edges of pulling attachment fit behind bearing.



Reverse idler shaft is pushed from transmission case. Legs of Push-puller are connected to housing with male-female adapters.



An internal pulling attachment is used in combination with a slide hammer to remove an oil seal from a housing.

(1-81)

Courtesy of Owatonna Tool Company

Correct Use Of Pullers

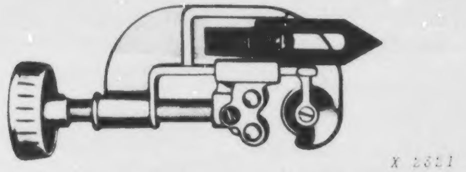
1. Don't use a hammer or a pry bar: use a puller.
2. Select the right size puller: the puller must have the correct reach and spread for the job.
3. Don't overload a puller:
    (a) For manual, screw-powered pullers, the puller screw must be at least half as large (in diameter) as the shaft of the pulling job.
    (b) For hydraulic pullers, the maximum force exerted in tons should be 7 to 10 times the diameter of the shaft in inches, e.g.,

For Shaft Diameter	Use Hydraulic Puller With
0 - 2"	17½ ton ram
2" - 3½"	30 ton ram
3½" - 5½"	50 ton ram

4. The tonnage capacity of a Push-puller is reduced as the legs get longer. Also, longer legs increases the chances of the legs bending, breaking or misaligning. Always use the shortest legs possible to do the job.
5. Place a shaft protector over the end of shaft before installing a puller.
6. Tighten the adjusting strap bolts when using a jaw puller.
7. Be sure the set up is rigid and the puller is square with the work.
8. Apply force gradually. The component should give a little at a time. Do not try to speed the removal by using an impact wrench on the screw.
9. If you have applied maximum force and the part does not move, go to a larger capacity puller.
10. Clean and lubricate the forcing screw frequently, from threads to tip, to give it long service life.
11. When installing parts that must be forced into place, normally go to a shop press rather than trying to use a puller. When in doubt ask for help.

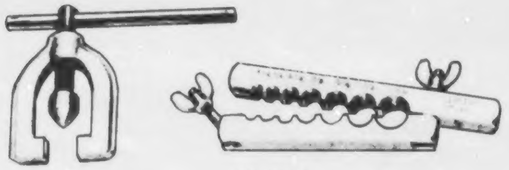
PIPE AND TUBING TOOLS

Tubing Cutter: used to cut tubing made of copper, aluminum, or steel (Figure 1-82). The cutter is clamped around to the tube and turned. As the tool is turned, a sharp wheel cuts into the tubing. Pressure is slowly increased by turning the knob on the end until the tube is cut off cleanly. Once cut, the end of the tube must be reamed back to size, otherwise flow in the tube could be restricted. The reamer attached to the cutter is used for this purpose. Tubing cutters are sold separately or sometimes in kits which include a cutter, a tube flaring tool, and a tube bending tool.



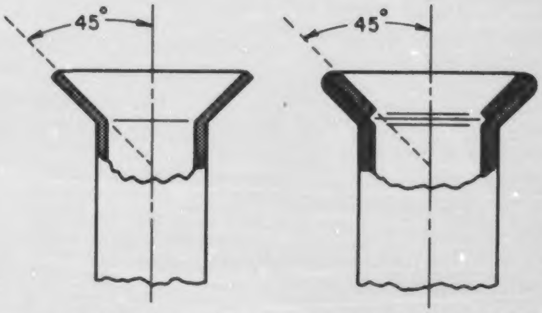
(1-82) TUBING CUTTER

Flaring Tool: is used to flare the end of copper, brass, steel, or aluminum tubing in preparation for a connection. To make a single flare the tubing is placed in the correct sized hole in the split support clamp (Figure 1-83) with the end of the tube protruding just beyond the clamp surface. Then the yoke part of the tool is placed over the clamp, and the threaded taper is tightened down on the end of the tubing. The taper causes the tube end to flare, providing a seal when the fitting is tightened. Note: don't forget to install the fitting before flaring the tube, because you can't put it on afterwards.



(1-83)

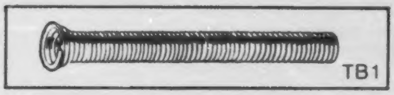
Single flares are adequate for some jobs, but in places where a stronger connection is required a double flare is used. A double flare is made in two steps. Using a part provided in flaring kits, the end of the tube is first folded inward (Figure 1-84). Then, the end is flared as described above.



SINGLE FLARE DOUBLE FLARE

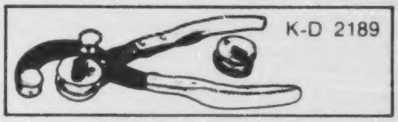
(1-84)

Bending Tool: is used to bend tubes uniformly without crimping them. To use a spring bender (Figure 1-85), slide the correct size bender over the tube, and bend it applying pressure with your thumbs. To use a plier-type bender (Figure 1-86), place the tubing in the shaped groove of the bender and squeeze the handles.



(1-85) SPRING-TYPE TUBE BENDER

Courtesy of Mac Tools



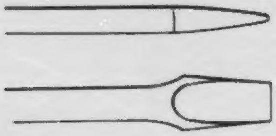
(1-86) PLIER-TYPE TUBING BENDER

Courtesy of Mac Tools

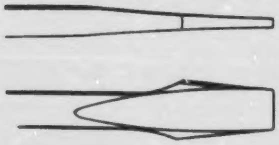
QUESTIONS — HAND TOOLS, SHOP SAFETY, SERVICE LITERATURE

1. The three basic pieces of information that should be in a parts list are:
   - (a) make, color, and size of the machine
   - (b) type, model, and size
   - (c) make, model, and serial number
2. True or False? A parts book and a service manual are essentially the same.
3. Fires are divided into how many classes?
   - (a) 2
   - (b) 4
   - (c) 5
   - (d) 3
4. True or False? Fire extinguishers are classed according to the type of fire they will extinguish.
5. List the six parts of the body a heavy duty mechanic can most commonly injure.
6. Which is a properly ground screwdriver, A or B?

A



B



7. Soft faced hammers are used rather than steel hammers because they:
   - (a) apply softer blows
   - (b) are quieter
   - (c) jar the hand less
   - (d) protect machined surfaces
8. True or False? Combination pliers are intended to be used as substitutes for wrenches.
9. Snap ring pliers are made for removing either ________ or ________ snap rings.
10. After cutting a piece of tubing with a tubing cutter, the end should be:
    - (a) filed smooth
    - (b) reamed
    - (c) left as is
    - (d) expanded
11. True or False? Use a double flare on tubing when a double nut is required.
12. The average lip clearance angle of a drill is from:
    - (a) 59° to 65°
    - (b) 8° to 12°
    - (c) 118° to 130°
13. If a drill bit runs off center when starting, it can be brought back by:
    - (a) using a larger drill bit
    - (b) leaning the drill to one side
    - (c) making another center punch mark
    - (d) making a chisel cut on the side to which the drill should be drawn
14. The narrow raised rib that runs the length of the twist drill and finishes the hole to size is called the:
    - (a) lip
    - (b) flute
    - (c) margin
    - (d) web
15. The size of a twist drill can be measured with a micrometer:
    - (a) over the land
    - (b) over the flutes
    - (c) over the margin
    - (d) over the web
16. Number drill sizes range from:
    - (a) No. 1 to 80
    - (b) No. 1 to 95
    - (c) No. 1 to 26
    - (d) No. 1 to 75

17. For general purpose work the cutting lips of a drill should be ground to an included angle of:
    - (a) 135°
    - (b) 118°
    - (c) 180°
    - (d) 145°

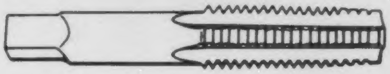
18. The difference between a tap and die is:
    - (a) a tap cuts threads in a hole, and a die cuts threads on a rod
    - (b) a tap cuts threads on a rod, and a die cuts threads in a hole
    - (c) a tap cleans threads, and a die cuts new threads

19. Three types of taps are:
    - (a) taper, pin, and bottoming
    - (b) taper, plug, and bottoming
    - (c) taper, bottom, and cape

20. A plug tap is used:
    - (a) to thread a blind hole
    - (b) after a taper tap
    - (c) before a taper tap
    - (d) after a bottom tap

21. Which of these taps is referred to as a plug?

(a)



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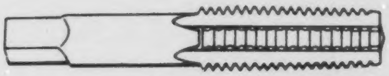

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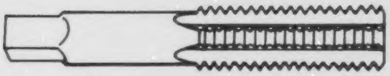


22. To remove a broken stud, center punch it, then:
    - (a) drill a large hole in the center
    - (b) drill a hole part way down
    - (c) drill a pilot hole
    - (d) drill it right out to the threads

23. What precaution must be taken with a reamer not to dull its cutting edge?

24. A multiplier is a geared attachment that gives a mechanical advantage through:
    - (a) bevel gears
    - (b) helical gears
    - (c) planetary gears

25. What are four common types of chisels used in the heavy duty trade?

26. The terms rough, smooth, and dead-smooth refer to:
    - (a) hacksaw blades
    - (b) drill tips
    - (c) file cuts

27. Name three common types of punches.

28. Name four types of screwdrivers.

29. Name four types of material used for hammer heads.

30. Name four types of pliers.

31. The file with the largest teeth is a:
    - (a) double-cut file
    - (b) flat file
    - (c) rough or coarse-cut file

32. A file that has two series of diagonal rows of teeth cut across its face is called:
    - (a) rasp cut
    - (b) double cut
    - (c) single cut
    - (d) fine cut

33. What does the term "drawfile" refer to?

34. What are the minimum number of hacksaw teeth that should be in contact with the work?

35. When cutting with a hacksaw, pressure should be applied to the blade:
    - (a) in both the forward and reverse stroke
    - (b) on the forward stroke only
    - (c) on the reverse stroke only

36. In reference to hacksaw blades, pitch refers to the ____________ per inch.

37. When really tightening a vise, it is advisable to tighten it with:

    (a) the handle of the vise only

    (b) a piece of pipe on the handle to get leverage

    (c) a hammer to strike the handle and secure the vise

38. What is the purpose of soft jaws for a bench vise?

39. Normally, hacksaw blade teeth should point:

    (a) toward the right hand

    (b) toward the handle

    (c) away from the handle

40. A typical box wrench has:

    (a) 10 notches

    (b) 8 notches

    (c) 12 notches

41. Wrench sizes are governed by the:

    (a) thread length

    (b) length of the bolt

    (c) width of the bolt head across the flats

    (d) width of the bolt head across the corners

42. What is the main rule when using an adjustable wrench?

43. Open and box end wrench sizes increase in steps of:

    (a) 1/8 inch

    (b) 1/16 inch

    (c) 1/32 inch

    (d) 1/46 inch

44. Spanner wrenches are used on nuts with:

    (a) 12 points

    (b) 6 points

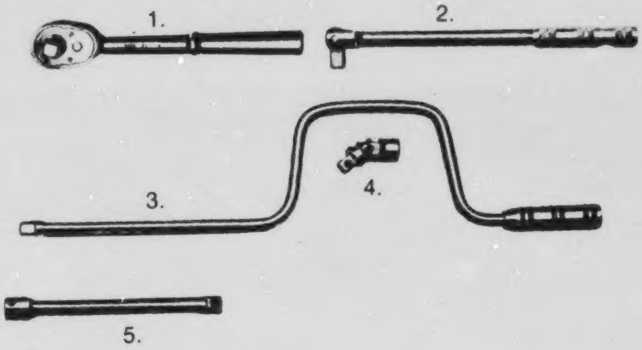
    (c) notches

    (d) flanges

45. Why is the head of an open end wrench made with an offset?

46. What is the advantage of a tubing wrench over a standard open-end wrench?

47. Identify the following socket drive accessores.



48. A torque wrench is recommended to provide:

    (a) extra leverage

    (b) adaptability of sockets

    (c) safeguard on over stressing parts

    (d) "non-slippage" of sockets

49. When the torque wrench lever length is 12 inches and the force applied to the handle is 5 pounds, the torque produced is:

    (a) 10 ft.-lbs.

    (b) 50 ft.-lbs.

    (c) 2 ft.-lbs.

    (d) 5 ft.-lbs.

50. In selecting the right sized puller, it must have the correct ____________ and ____________ for the job.

51. For hydraulic pullers, the maximum force exerted in tons should be ____________ times the diameter of the shaft in inches:

    (a) 1 to 2

    (b) 4 to 5

    (c) 12 to 15

    (d) 7 to 10

52. A good rule with pullers to prevent bending, breaking or misaligning the puller legs is to use:

    (a) the largest legs possible
    (b) the shortest legs possible
    (c) the smallest legs possible
    (d) the straightest legs possible

53. The point of a soldering iron must be ____________ before being used for soldering.

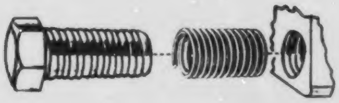
54. What is the purpose of soldering flux?

55. Soldering electrical wiring should be done with solder and:

    (a) resin flux
    (b) acid flux
    (c) caustic flux
    (d) soap flux

56. The figure below shows installation of a:

    (a) bolt
    (b) heli-coil
    (c) spring



AIR, ELECTRIC, AND HYDRAULIC POWER TOOLS

IMPACT WRENCHES

Impact wrenches are driven by air (Figure 1-87) or by electricity; they work in either direction, and come with 3/8" 1/2", 3/4" and heavy duty 1" drives. Their advantage over hand wrenches is that they are much quicker and require less effort to use. The time taken to do such jobs as loosening or tightening wheel nuts or U-bolt nuts will be cut in half by using an impact wrench. A rule of thumb on when to use impact wrenches is to use them wherever possible to save time and energy. However, where torque is critical, do final tightening with a torque wrench.

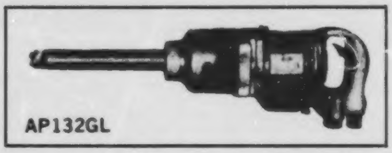
Correct Use

Some impact wrenches have an adjustment to gauge the amount of torque the wrench delivers, but most don't. Since it's very easy to overtighten nuts with an impact wrench, it's necessary to develop a feel for how much torque the impact wrench puts on nuts. To help get this feel, tighten a few nuts with an impact wrench and then put a torque wrench on the nut and see how much torque you have applied. Be alert when using an impact wrench: don't damage parts by overtightening them.

Air impact wrenches require lubrication. See the maintenance instructions for the wrench or ask a journeyperson. Three methods of lubricating air wrenches are (1) a special lubricator located in the incoming air line, (2) an oil reservoir in the handle or (3) squirting lubrication into the air intake by hand. Electric impact wrenches are usually lubricated by the manufacturer on assembly, but should occasionally be cleaned and relubricated.

MAC TOOLS
MI140

1/2" DRIVE AIR WRENCH



1" DRIVE IMPACT WRENCH

(1-87) IMPACT WRENCHES

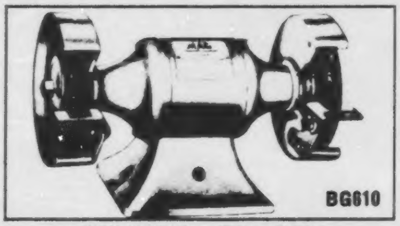
Courtesy of Mac Tools

BENCH GRINDER

All repair shops have bench grinders (Figure 1-88). They are used for sharpening, cleaning, shaping, wire brushing, buffing. Bench grinders have two drives. Often a medium-grit grinding wheel will be on one side and a fine wheel or wire brush on the other.

Correct Use

1. The shaft that holds the right-hand wheel has right-hand threads, while the shaft that holds the left-hand wheel has left-hand threads. Remember this when changing grinding wheels.
2. Tool rests should be approximately **1/16"** from the wheel and should be at or below the center of the wheel. Rests can be set at various angles for sharpening tools.
3. Take the following safety precautions when grinding: always wear safety glasses even if the grinder has a shield. Never wear loose clothing or jewelry. Don't have anything near the grinder that a spark could explode.
4. Place the work on the tool rest when grinding: don't lift it up.
5. Move the work back and forth across the wheel so that the wheel doesn't develop a groove. Don't use a wheel that is cracked or flawed.
6. Dip the work frequently so that it doesn't lose its temper.
7. Give a wheel a chance to warm up: don't start right in heavily grinding on a cold wheel.



(1-88) BENCH GRINDER

Courtesy of Mac Tools

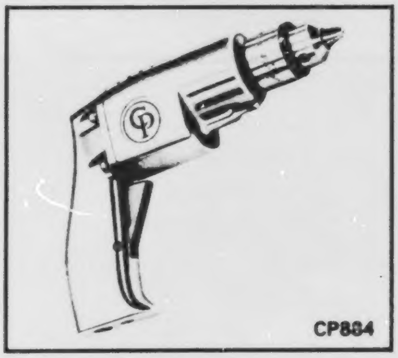
PORTABLE GRINDERS

Hand held, electric and air grinders are also available. They are made in sizes ranging from small light-duty models with specially shaped grinding bits to larger heavy duty ones suitable for continuous grinding. Many portable grinders have accessories that can do other jobs such as sanding, brushing, buffing, filing. Portable grinders are used when the work can't be brought to a bench grinder, or, in the case of small specialty grinding jobs when the bench grinding wheel is not the right shape. Always use two hands on a portable grinder: never try to operate it with one hand.

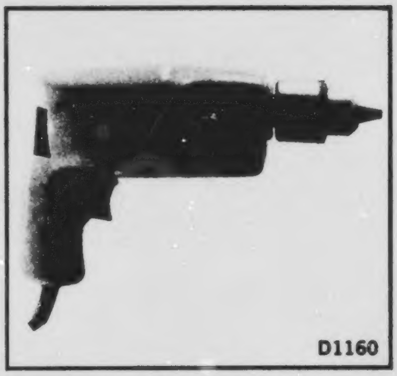
The same precautions that apply to bench grinders also apply to portable ones. In addition, keep the electric cord or air hose free of the grinding wheel.

HAND DRILLS

Electric and air (pneumatic) hand drills (Figure 1-89) are available in 1/4", 3/8" and 1/2" chuck sizes. Larger sizes are made but they are not very common. Of the three drill sizes, the quarter-inch drill has the fastest speed but the lowest torque. It is made for drilling holes in steel up to one-quarter inch in diameter. Similarly, a 3/8 inch drill (medium speed, medium torque) is used for drilling holes up to 3/8 inch diameter, and a 1/2 inch drill (low speed, high torque) for holes up to 1/2 inch. Within each electric drill chuck size, various strengths and qualities of motors are made, some for light occasional use and others for heavy continual use. The motors and switches on hand drills are either straight on-off or are variable speed (air drills are all variable speed). Some drills have forward drive only while others have reverse and forward.



3/8" AIR DRILL

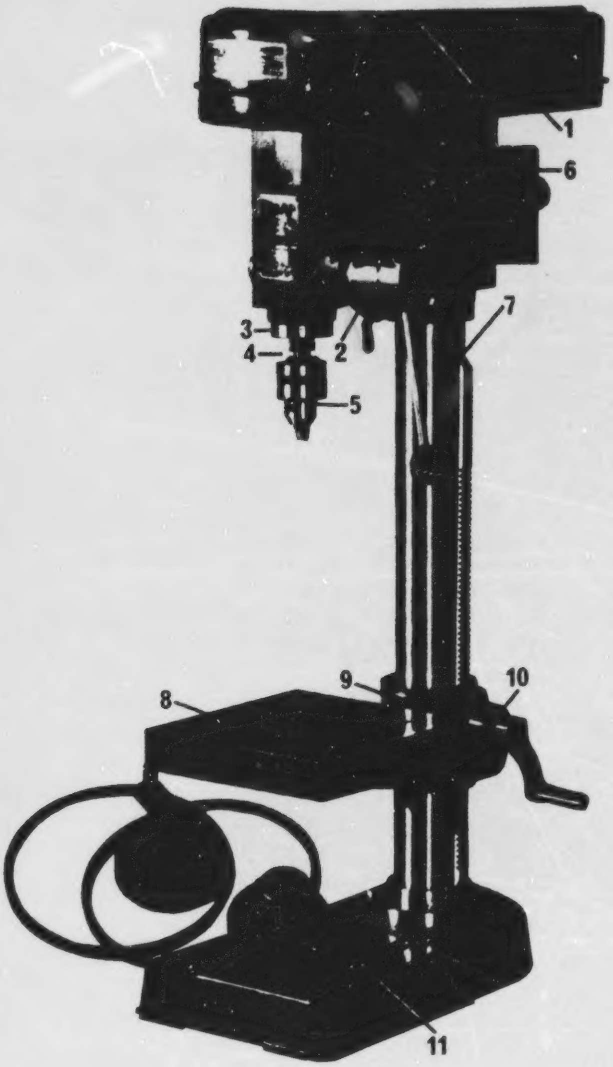


1/2" SINGLE SPEED
ELECTRIC DRILL

(1-89) HAND DRILLS
Courtesy of Mac Tools

Correct Use

1. Select the correct size hand drill for the job.
2. Insert drill bits fully into the chuck and tighten the chuck with a key.
3. Avoid excessive pressure when drilling. In other words, keep twist drills sharp.
4. When drilling steel keep the twist drill and work cool by using lubricating oil. The oil will also aid the bit in cutting.
5. Don't let hand drills overheat. Remember light duty drills are not intended for long periods of continual use.
6. Air drills, like air impact wrenches, require lubrication. See the drill maintenance instructions or ask a journeyperson. Air drills also have air strainers that occasionally need cleaning.
7. When using an electric drill, or any electric hand tool, make sure it is properly grounded.
8. If you have to use an electric drill a long ways from the source of electricity, have an extension cord of proper size to prevent voltage drop.



(1-90) DRILL PRESS

Courtesy of Malkin and Pinton Industrial Supplies

FEATURES

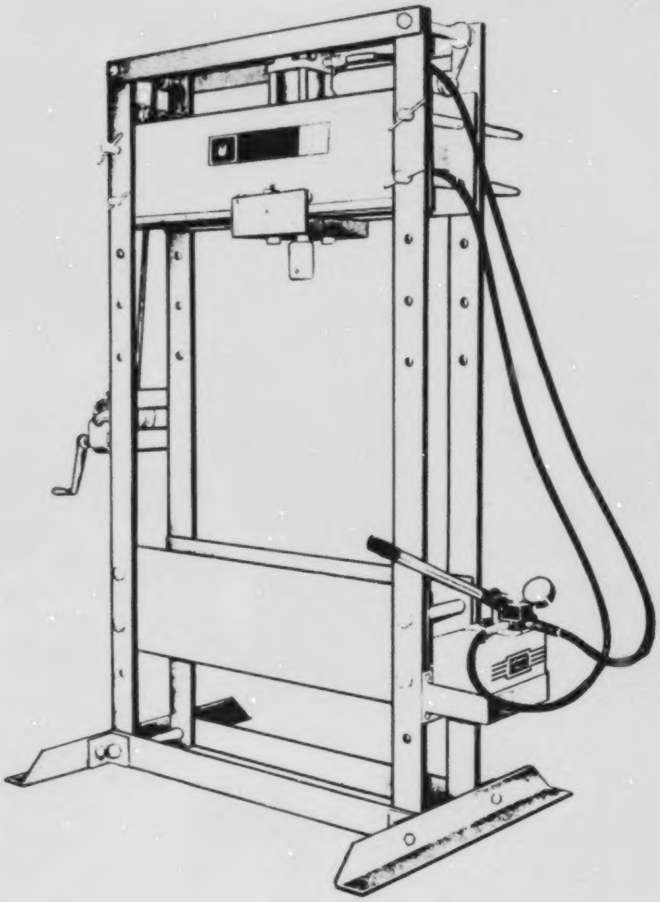
1. Hinged Steel belt and pulley cover.
2. Ring-lock depth stop for positive depth control.
3. Ball bearing quill.
4. Quill stroke, approximately 3$^{1}/_{2}$''.
5. 1/2'' capacity 3 jaw key-type belt tension device for quick speed changes.
7. Machined column.
8. Slotted cast iron worktable, machined surface, (approximately 9$^{1}/_{2}$'' square).
9. Table tilts 45 degrees right and left. Pointer and degree scale.
10. Geared table raising-lowering mechanism with positive lock.
11. Cast base with machined top and "T" slots.

A drill press (Figure 1-90) is an electric vertical drill that is moved up and down a carriage by a hand lever. The press stand has a bed plate on which the work can be clamped. Drill presses are capable of greater drilling accuracy than hand drills because once the work is securely clamped to the bedplate there can be no movement of the drill bit in relation to the work. The hole is drilled exactly where you want it and is perfectly straight (or at the desired angle). Drill press speed-torque ratios can be adjusted on most presses by adjusting the V-belt to different sized pulleys on the drive and driven shafts. On large floor models having gear drive, the gears are shifted to give speed and torque changes. Typical uses for drill presses in a heavy duty shop are:

- — Drilling steel plates or angle and channel iron when fabricating.
- — Drilling out broken studs or parts that can be moved to the drill press.

Correct Use

1. Keep the bedplate clean.
2. Use a piece of wood or steel under the work you are drilling to protect the bedplate.
3. Use the correct drill speed.
4. Keep drill bits sharp.
5. Clamp the work securely.
6. Don't force the drill.
7. Use ample lubrication for cooling and cutting.
8. Remove the chuck key after removing the drill.



(1-91) STANDING HYDRAULIC PRESS

Courtesy of Owatonna Tool Company

HYDRAULIC POWER TOOLS

Heavy duty mechanics use the following hydraulic tools: presses, pullers, jacks and hoists. These tools can be either portable or stationary and are basically used for pushing, pulling or lifting.

PRESSES

Presses are rated according to their pushing capacity in tons. They range from small 10-ton bench models to large 150-ton (and higher) standing models. Presses are a shop tool and are not considered portable. They are made with either the table or the adjustable hydraulic head assembly. Note in Figure 1-91 the large pins supporting the hydraulic head assembly and the holes in the side rack for varying the height. A small hand winch on the left side of the press has a cable arrangement connected to the hydraulic head assembly to raise and lower the head. Plates across the top of the table are used for pressing on. The press's hydraulic pump can be a hand type, as shown, or be electric, depending on the size of the press. A gauge mounted on the pump gives the force in tons being applied.

Correct Use

1. A press is used with parts having an interference fit. Always keep in mind that presses can apply a tremendous force. Not paying attention when pressing could cause injury to you or to someone working nearby and in addition break the parts.
2. Press on the correct spot, e.g., to remove a bearing on a shaft press on the bearing's inner race.
3. Stand to one side while operating the press.
4. Observe the amount of force being applied.
5. Wear a face mask in case something should break.
6. Carefully support the part being disassembled.
7. Know how the pieces come apart before attempting to apply force.
8. Make sure weight is off the cables and support pins are fully installed.

PULLERS

There are many types of hydraulic pullers all of which are portable. A hydraulic puller assembly has a puller, a pump and reservoir, and an adapter.

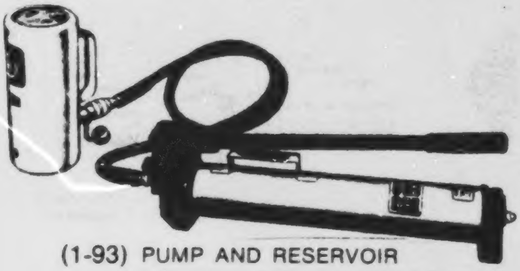
Hydraulic pullers are made with single and double-acting rams and with a variety of pulling capacities. Examples of single and double-acting pullers are shown in Figure 1-92.

17 ½ TON
30 TON
50 TON
100 TON
DOUBLE-ACTING

(1-92) PULLERS

Courtesy of Owatonna Tool Company

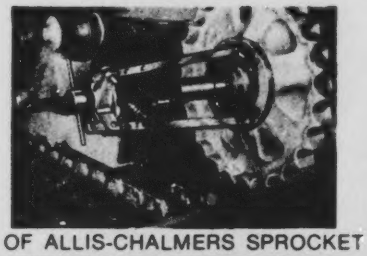
Pumps are available in different sizes, and have quick couplers on their hose ends. Single acting pullers require pumps with single hoses, while double-acting pullers need pumps with two hoses and valving to allow the oil to be pumped in either direction. A pump and reservoir for a single acting puller is shown in Figure 1-93.



(1-93) PUMP AND RESERVOIR

Courtesy of Owatonna Tool Company

Examples of various puller adapters in use are shown in Figure 1-94.

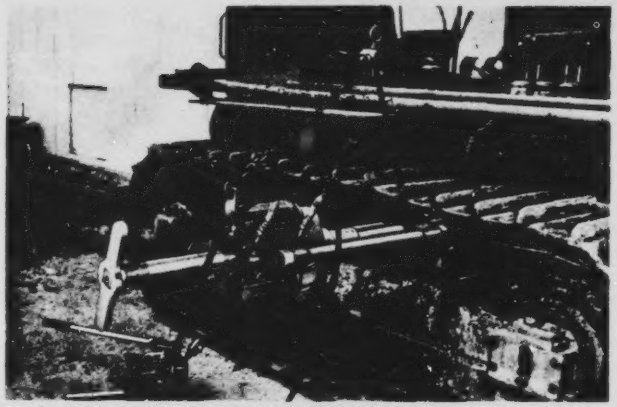


REMOVAL OF ALLIS-CHALMERS SPROCKET

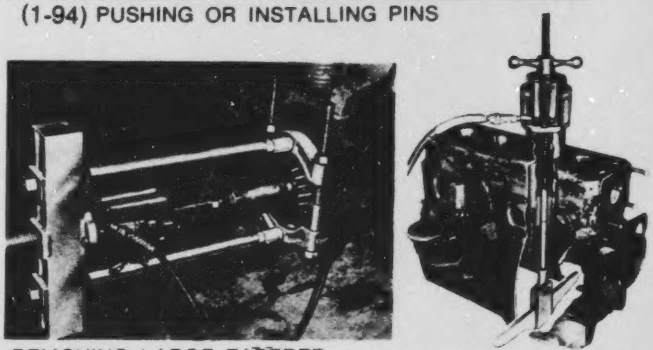
INSTALLATION OF CATERPILLAR SPROCKET

(1-94) PULLERS IN USE

Courtesy of Owatonna Tool Company



(1-94) PUSHING OR INSTALLING PINS



REMOVING LARGE TAPERED ROLLER BEARING CONE

REMOVING A SLEEVE

(1-94)

The same safety rules apply to portable pullers as to shop presses. Know how an assembly comes apart before applying force, and apply the force with caution.

STEAM CLEANERS

There are a number of steam cleaners, each with its own specific instructions for start and stop procedures. General information on portable steam cleaners is discussed here.

To operate, steam cleaners need the following:

- power supply, either 120 V or 220 V
- adequate water supply
- fuel oil or natural gas, depending on the machine.

Procedures for starting a steam cleaner are usually done in this order:

1. Connect the power supply.
2. Connect the water and turn on the tap.
3. Turn on the motor switch and let the machine run until the water is fully circulating, i.e., water is discharging from the steam nozzle.
4. Turn on the fuel and ignite it. Let the machine warm up.
5. Adjust the discharge pressure and cleaning solution, as directed by the machine's instructions.

Caution: Always wear a face mask, rubber gloves, and a waterproof apron or waterproof clothing when steam cleaning.

For shutdown:

1. Shut off the fuel.
2. Let the machine run until it cools, then shut off the motor switch. Note that some machines are equipped with an automatic shut off when the temperature drops to a safe level.
3. Shut off the water supply and disconnect the hose.
4. Disconnect the power supply.

To obtain maximum life from a steam cleaner follow these few simple rules.

1. Use only the recommended cleaning soap.
2. Use clean fuel and service the filter regularly.
3. Have complete circulation of the water before turning the heat on.
4. Let the machine adequately cool before shutting off the circulating pump.
5. Clean the steam cleaner after use. Oil and grease will soon deteriorate it.
6. After cold weather operation, store the machine in a warm area.
7. Always make sure the machine has an adequate water supply.

QUESTIONS — AIR, ELECTRIC AND HYDRAULIC POWER TOOLS

1. On a bench grinder, the maximum clearance between the wheel face and tool rest should not exceed:

   (a) 3/8″

   (b) 1/16″

   (c) 1/4″

   (d) 1/8″

2. True or False? Air impact wrenches require lubrication.

3. When grinding, it is important to keep the work __________.

4. What is the advantage of a drill press over a power hand drill?

5. When using impact wrenches, care must be taken not to ______________ nuts.

6. What should you know about parts before pressing them apart?

7. What are the three essential parts of a hydraulic puller assembly?

8. What is the difference between a 3/8″ and a 1/2″ power hand drill?

9. True or False? To start a steam cleaner first ignite the fuel, then turn on the water.

MEASURING TOOLS

CALIPERS AND DIVIDERS

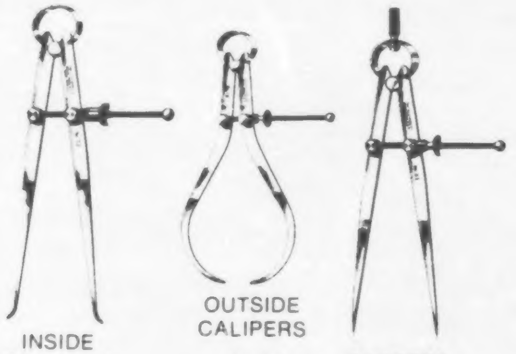
Having no scales of their own, calipers and dividers (Figure 1-95) are used in conjunction with steel rulers. The caliper or divider measures a part and then is transferred to a ruler to find the measurement in inches or centimeters. Or vice versa, the caliper is set on a ruler first and then the measurement is transferred to the part.

Depending on the quality of the caliper, the care with which the measurement is taken, and the accuracy of the ruler, calipers can be accurate to within 1/32 to 1/64 of an inch. Common shop uses for calipers and dividers are:

Outside Calipers: to find a shaft or pipe outside diameter when a rough measurement is needed.

Inside Calipers: To take the inside diameter of a hole and compare it to the ID of a seal or bearing.

Dividers: To transfer a dimension from a ruler to something you are making. A divider can also be used to scribe a circle on a piece of metal.



INSIDE CALIPERS

OUTSIDE CALIPERS

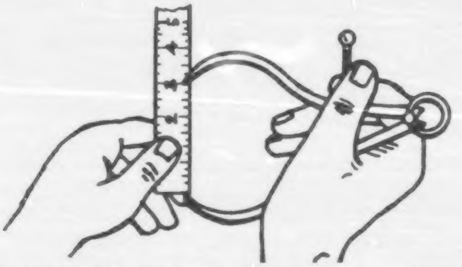
DIVIDERS

(1-95)

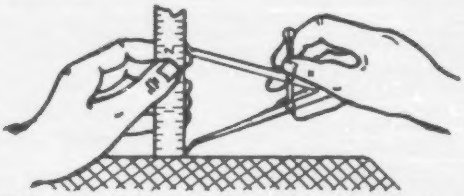
Courtesy of L.W. Starrett Company

Correct Use:

1. When using outside calipers, adjust the legs so that they are just a little wider than the part. Then tighten the adjusting nut until the legs touch the part. With inside calipers do the opposite: start with the legs a little shorter and adjust them outward.
2. The method of transferring caliper measurements to a ruler are illustrated in Figure 1-96.



OUTSIDE CALIPER HELD AGAINST A STEEL RULE TO CHECK OR SET A SIZE



INSIDE CALIPERS HELD AGAINST A FLAT SURFACE AND ALONG THE EDGE OF A STEEL RULE TO CHECK OR SET A SIZE

(1-96)

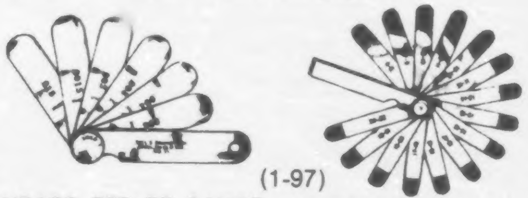
FEELER GAUGES

Feeler gauges (Figure 1-97) are precision measuring tools for checking small clearances. There are two common types of feeler gauges: standard and stepped.

Standard feeler gauges have several blades arranged around a common pivot. The thickness of each blade is marked in thousandths of an inch. For example, "066" indicates six-thousandths of an inch. A blade marked "6" indicates the same thing.

Stepped feeler gauges (also referred to as a go-no-go gauge) have blades that have two thicknesses. The tip of the blade is one thickness, while the rest of the blade is two-thousandths of an inch thicker. Stepped feeler gauges are convenient for making quick, approximate measurements.

For thicknesses more than about 25 thousandths of an inch, wire feeler gauges are often used. Wire feeler gauges are used, for example, to measure spark plug gaps.



(1-97)

STANDARD FEELER GAUGE

STEPPED FEELER GAUGE

X 2325

Courtesy of John Deere Ltd.

Correct Use

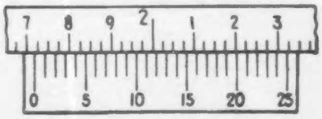
1. Never wedge blades of the gauge in the clearance space. If the blade being tried cannot enter the space without forcing it, use a thinner blade, or adjust the clearance to conform to the blade.
2. Never bend or twist the blades.
3. When in doubt about the thickness of a blade, measure it with a micrometer.
4. Occasionally wipe the blades clean with an oily cloth to remove dirt and prevent rusting.
5. If blades on a standard feeler gauge get rough, worn, bent at the tips, cut off the damaged portion of the blade.

VERNIER CALIPER

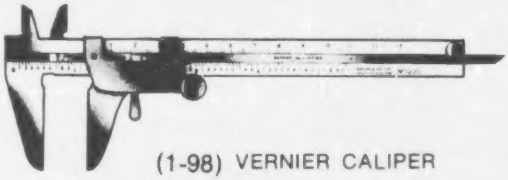
Some precision made parts require more accurate measurement than standard calipers can give. To measure these parts a Vernier caliper (Figure 1-98) can be used; it is accurate to within one thousandth (.001) inch or one hundredth (.01) millimeter. Many Vernier calipers have two sets of jaws, one for inside and one for outside measurements. Three types of Vernier calipers are available. A quick change Vernier caliper has one adjustment: the moveable jaw is slid into contact with the part and the measurement is read. A master Vernier caliper has two adjustments: it has a fine adjustment that is used after the moveable jaw has made contact. There are also Verniers with dial indicators instead of scales; these are easier to read than scales.

Directions follow on how to read a Vernier scale:

To read the Vernier scale at the right:

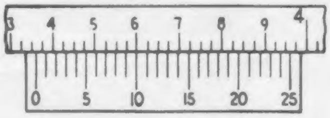


1. Take the reading from the zero on the bottom scale, the Vernier scale, and read the whole inches first (the 0 comes between 1 and 2 inches). 1.000
2. Read the tenth divisions next (just over 7). .700
3. Read the fortieth divisions next (each of the four divisions between 7 and 8 tenths counts .025 inch). The 0 doesn't quite reach the first mark, and so there is nothing here. Note some Vernier scales will have only two divisions between the tenths and each of them will count for .05 inch). .000
4. Read the Vernier last (find the point on the Vernier that perfectly lines up with a line on the scale above. In this case it is 23. Note this Vernier goes up to 25. Some will go to 50). .023
5. Now add these up and the reading is: 1.723



(1-98) VERNIER CALIPER

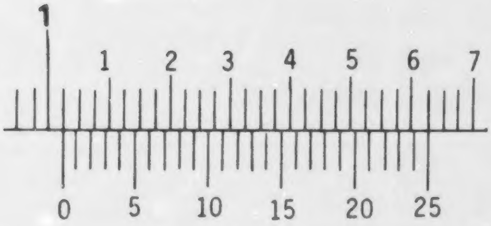
Another example; read the Vernier scale at the right:



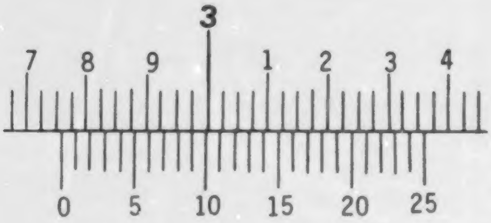
1.	Whole inches	3.000
2.	Tenths	.300
3.	Fortieths (2 × .025 = .050	.050
4.	Vernier	.007
5.	Reading	3.357 inches

Try these Vernier readings; the answers are given below.

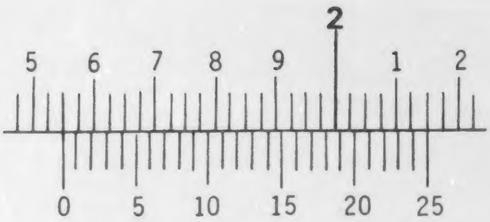
1


1
1 2 3 4 5 6 7
0 5 10 15 20 25

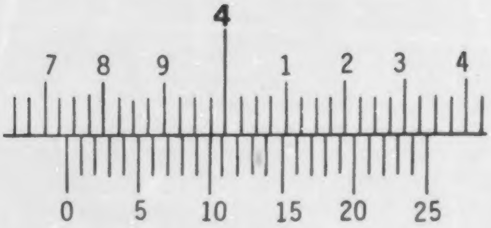
2


3
7 8 9 1 2 3 4
0 5 10 15 20 25

3


2
5 6 7 8 9 1 2
0 5 10 15 20 25

4

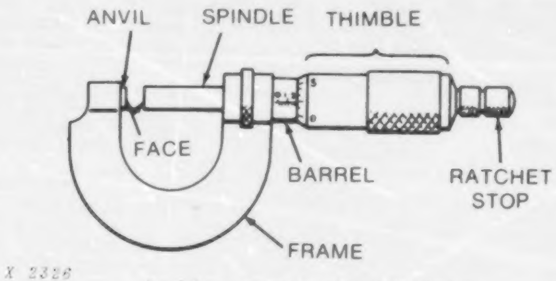

4
7 8 9 1 2 3 4
0 5 10 15 20 25

Answers:

1. 1.025
2. 2.759
3. 1.550
4. 3.735

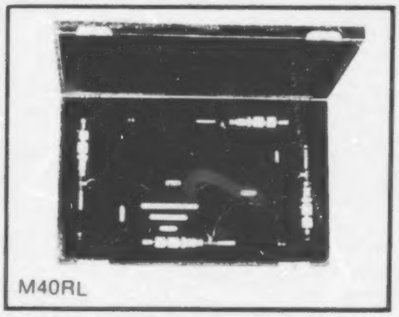
MICROMETERS

Outside Micrometers: used to accurately measure the diameters or thicknesses of parts. Standard micrometers (Figure 1-99) have an adjusting range of one inch. Outside micrometers are available in sets as shown in Figure 1-100. The sets contain four or five micrometers, one to measure distances between 1 and 2 inches, another to measure distances between 2 and 3 inches, and so on up to 5 or 6 inches. Micrometers can also be purchased individually. A third type of micrometer arrangement on the market is a single micrometer that will measure distances in a range, for example, from 0-6". In this case the micrometer has a 6" frame with one inch travel on the spindle and replaceable anvils in the increments of 1", i.e., 5", 4", 3", 2", etc.



(1-99) OUTSIDE MICROMETER

Courtesy of John Deere Ltd.

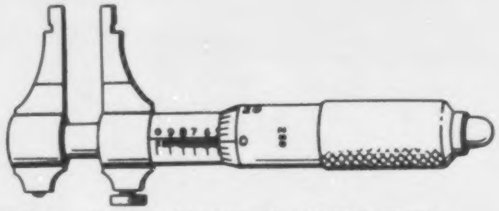


(1-100) OUTSIDE MICROMETER SET

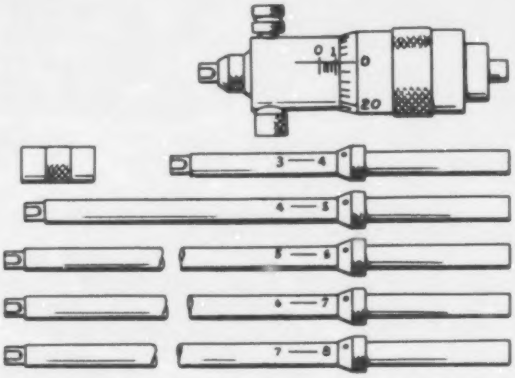
Courtesy of Mac Tools

Inside Micrometers: used to accurately measure inside diameters or distances. Inside micrometers, like outside micrometers, also have an adjusting range of an inch. There are two types of inside micrometers: one for measuring small dimensions and the other for large dimensions. The latter has several extensions (Figure 1-101).

Depth Micrometers: used to measure the depth of openings or protrusions (Figure 1-102). Depth micrometers are adjusted and read like the other micrometers. Also, like the other micrometers, their travel is limited to one inch, thus they are made with various extensions.



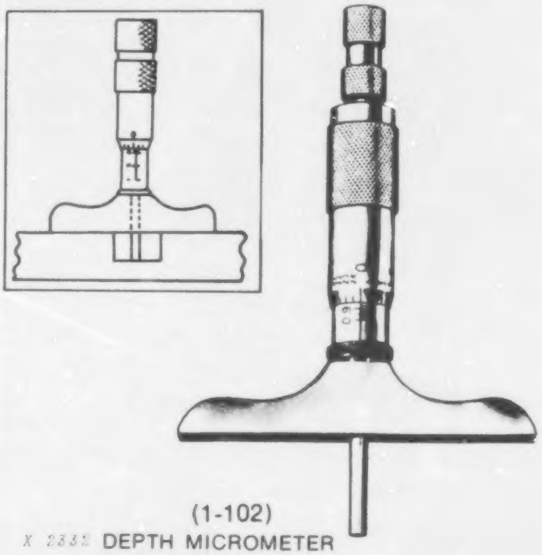
SMALL INSIDE DIAMETER MICROMETER



LARGE INSIDE DIAMETER MICROMETER

(1-101)

Courtesy of John Deere Ltd.



(1-102)
DEPTH MICROMETER

Courtesy of John Deere Ltd.

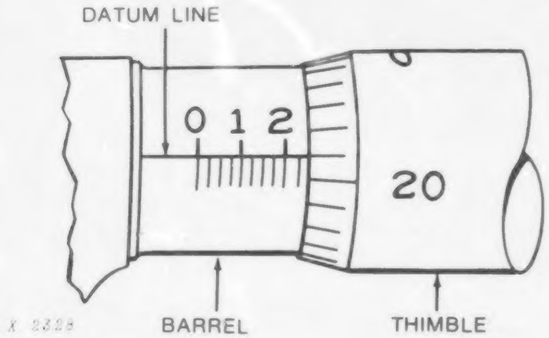
READING MICROMETERS

Inside and Outside Micrometers

Inside and outside micrometers are read in the same way. Refer to Figure 1-103. Note the gradations on the barrel and the thimble: each mark on the datum line on the barrel represents twenty-five thousandths (.025) of an inch, while each mark on the thimble represents one thousandth (.001) of an inch. On the datum line 4 marks make one-tenth (.1) of an inch, since 4 × .025 = .1. Therefore, the 0, 1, 2, 3, etc., that you see on the datum line represent tenths of an inch, e.g., 3 is .3 of an inch. The numbers on the thimble, 0, 5, 10, 15, 20, represent thousandths of an inch, e.g., 17 is .017 of an inch.

The reading on Figure 1-103 is taken as follows:

1. Highest tenth visible on datum line (2)	.200
2. Number of marks beyond the 2 tenths (one so 1 × .025 = .025)	.025
3. Thimble reading (21. Note if thimble mark doesn't line up exactly with datum line read to the nearest mark).	.021
4. Add to get the reading. Now depending upon the size of the micrometer the measurement of the part would be 1, 2, 3 or 4 inches plus the .246 inches.	.246

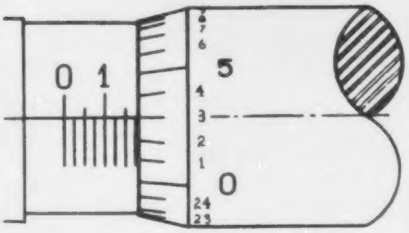


(1-103) MICROMETER GRADUATIONS

Courtesy of John Deere Ltd.

Another Example (Figure 1-104):

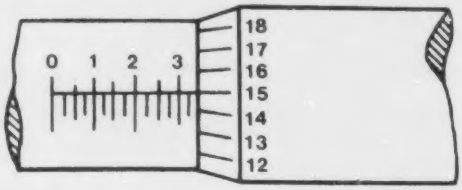
1. Highest tenth (1)	.100
2. Number of marks beyond one tenth (three so 3 × .025 = .075)	.075
3. Thimble reading (3)	.003
4. Total	.178



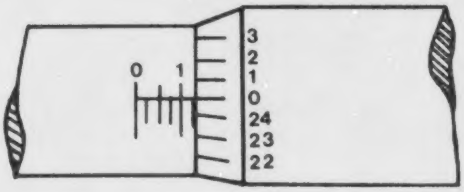
(1-104)

Try these micrometer readings; the answers are given below.

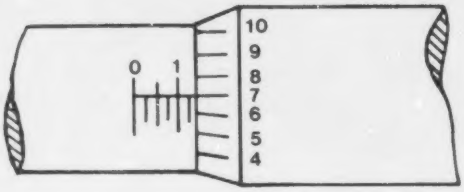
1


0
1
2
3
18
17
16
15
14
13
12

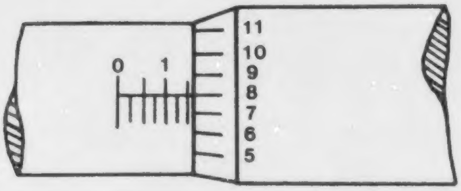
2


0
1
3
2
1
0
24
23
22

3


0
1
10
9
8
7
6
5
4

4


0
1
11
10
9
8
7
6
5

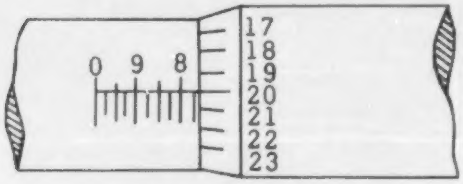
Answers:

1. .340
2. .125
3. .132
4. .158

Depth Micrometers

Although the basic procedure for reading a depth micrometer is the same as for reading inside and outside micrometers, there is a difference. In the former you read on the barrel what is covered up by the thimble, whereas in the latter you read what is exposed on the barrel.

Look at the depth micrometer reading in Figure 1-105.


0
9
8
17
18
19
20
21
22
23

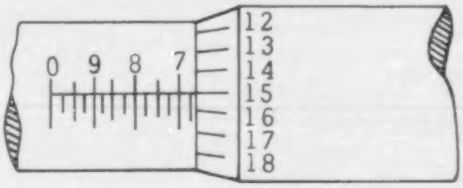
(1-105)

The reading is taken as follows:

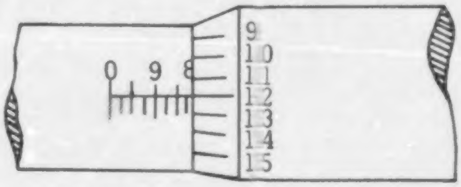
1.	Highest tenth covered by the thimble (7)	.700
2.	The number of marks beyond the seven tenths (two since there's only one remaining, so 2 × .025 = .050).	.050
3.	Thimble reading (20).	.020
4.	Total.	.770

Try the following depth micrometer readings. The answers are given below:

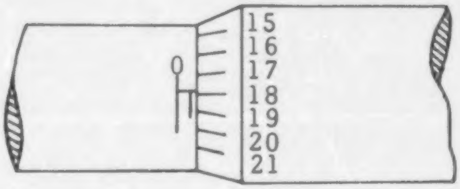
1


0
9
8
7
12
13
14
15
16
17
18

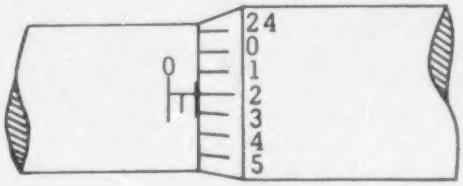
2


0
9
8
9
10
11
12
13
14
15

3


0
15
16
17
18
19
20
21

4

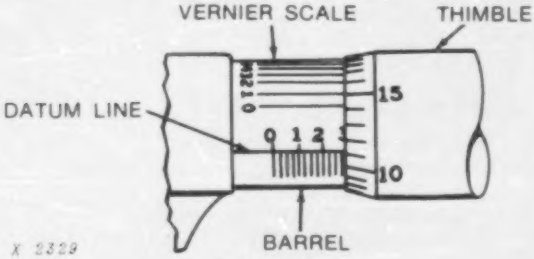


Answers:

1. .665
2. .812
3. .968
4. .952

Vernier Micrometers

If more accurate readings are desired, use a Vernier micrometer (Figure 1-106). This micrometer has a Vernier scale on the barrel which divides thousandths on the thimble into tenths making it possible to make a measurement to one ten-thousandth (.0001) of an inch. Vernier micrometers are read the same as outside micrometers except with one extra step: look for a mark on the Vernier scale that lines up with a mark on the thimble. That mark on the Vernier scale is the number of ten thousandths of an inch.

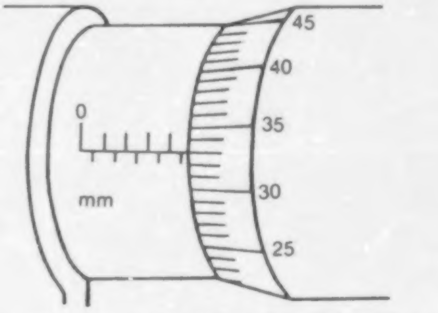


(1-106) MICROMETER WITH VERNIER SCALE
Courtesy of John Deere Ltd.

Metric Micrometers

There are two sets of marks on the datum line of a metric micrometer (Figure 1-107). The marks above the line represent whole millimeters (mm). The marks below the line are half millimeters (.5 mm). The graduated marks on the thimble represent hundredths of millimeters, e.g., 24 would be .24 mm. To find the reading in Figure 1-107:

1. Whole millimeters (4).	4.00
2. Half millimeter (yes)	.5
3. Thimble reading.	.33
4. Add to get the reading.	4.83 mm



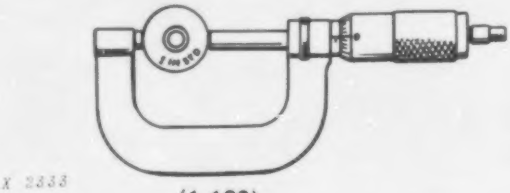
(1-107) METRIC MICROMETER READING

Correct Use Of Micrometers

1. Select the right size micrometer. Adjust (1) an outside micrometer so that it is a little larger than the part to be measured, (2) an inside micrometer so that it is a little smaller and (3) a depth micrometer so that it is a little shallower. Adjust the thimble until contact is made. If the micrometer is equipped with a ratchet stop, turn it until at least two clicks can be heard. Some micrometers do not have a ratchet stop; for these a feel has to be developed to know when the correct contact pressure is made.
2. Never tighten micrometers so tight that work cannot be drawn from them.
3. Do not slide a micrometer back and forth excessively across the work because this will wear away the contact surfaces and make the micrometer inaccurate.
4. To get a more accurate reading, take the reading, if possible, before removing the micrometer from the work. If this can't be done, remove the micrometer very carefully so as not to disturb the setting.

Caring For Micrometers

1. Avoid placing micrometers where they will become heated.
2. Check micrometers periodically with a master gauge or standard to ensure their accuracy (Figure 1-108).
3. Keep micrometers in cases or boxes to protect them from grit and dirt.
4. Never allow a micrometer to become rusty or dirty. Wipe them with a clean cloth oiled with a few drops of fine machine oil.
5. Always be sure micrometer contact faces are clean before measuring. Never use anything abrasive for wiping faces clean.
6. If a micrometer is dropped, don't use it again until it has been checked on a master gauge or standard.

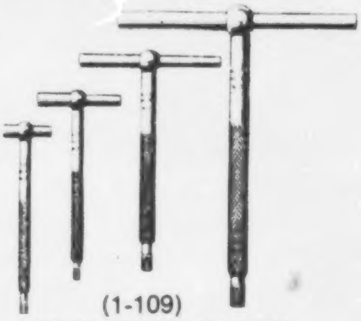


(1-108)
CHECKING MICROMETER WITH STANDARD
Courtesy of John Deere Ltd.

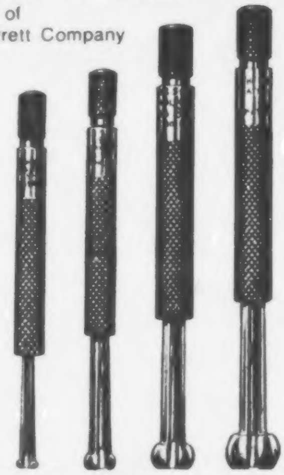
TELESCOPING GAUGES AND SMALL HOLE GAUGES

For hard to reach inside or outside measurements, use standard calipers to measure the part and then transfer the measurement to a micrometer: an inside micrometer for an outside caliper, and vice versa, an outside micrometer for an inside caliper. Or, if a more accurate inside reading is required, use a telescoping gauge or a split-ball gauge. Telescoping gauges are "T" shaped with spring-loaded plungers (Figure 1-109). When the gauge is put into a hole, a lock is loosened and the spring plunges move out against the walls. The lock is then tightened, tilted and carefully withdrawn. An outside micrometer is used to take the measurement across the plungers. Telescoping gauges are available in different expansion ranges and handle lengths.

The split-ball gauge (often called a small-hole gauge Figure 1-110) is used similarily to a telescoping gauge. The ball is inserted in the hole, allowed to expand, then locked. An outside micrometer is used to take the measurement across the ball.



(1-109)
TELESCOPING GAUGES
Courtesy of
L.W. Starrett Company

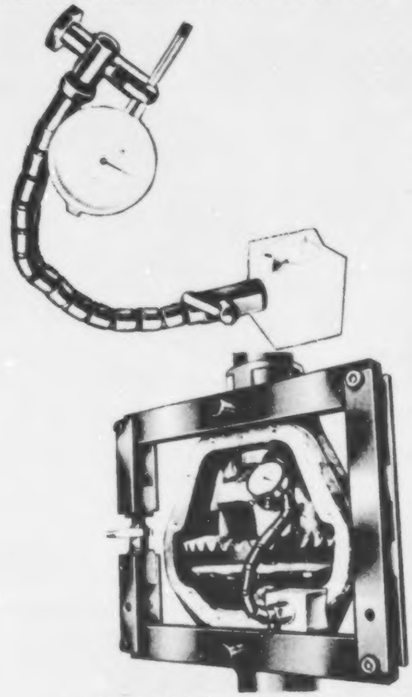


(1-110)
SMALL HOLE GAUGES

Courtesy of L.W. Starrett Company

DIAL INDICATORS

Dial indicators (Figure 1-111) measure the movement in shafts or gears which have adjustable end-play or back lash, e.g., the drive axle ring gear. Some other uses are to accurately measure travel such as injector movement, to measure wear such as on a cylinder taper, and to measure runout. They are available in various accuracy ranges from .001" to .00005", and in various lengths of travel measurements from 12" to .003".



(1-111) DIAL INDICATOR
Courtesy of Owattona Tool Company

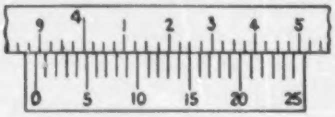
Correct Use and Care

1. Dial indicators must be securely mounted so that the contact rod is in line with the movement of the bearing or shaft to be measured. Some indicators have a magnetic base with a sliding adjustable arm, while others have bolt-on brackets. To record full movement of the part, pry the part in both directions, noting the full range of movement on the indicator dial.
2. Dial indicators, like micrometers, are sensitive instruments and require special care to keep their readings accurate. Store indicators in a clean, dry place. Never drop them. Don't allow the spring loaded plunger to snap back when depressed as it could damage the meter movement.

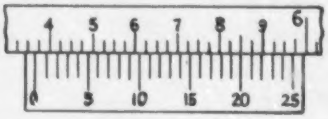
QUESTIONS — MEASURING TOOLS

1. Calipers are generally used in conjunction with a:
   - (a) dial indicator
   - (b) steel rule
   - (c) inside micrometer
   - (d) vernier caliper
2. Find the following vernier caliper readings:

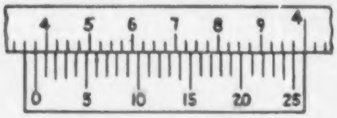
(a)


9
4
1
2
3
4
5
0
5
10
15
20
25

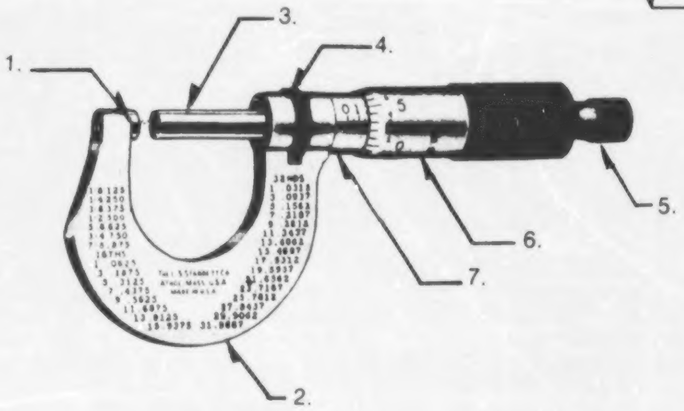
(b)


4
5
6
7
8
9
6
0
5
10
15
20
25

(c)

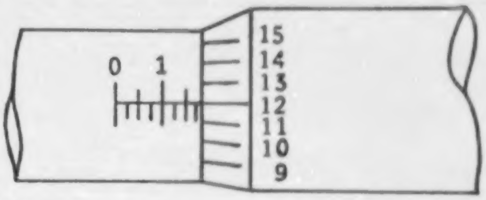

4
5
6
7
8
9
4
0
5
10
15
20
25

3. Identify the numbered parts:

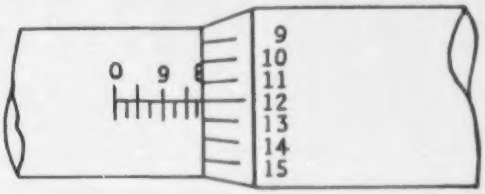


4. A four-inch micrometer measures objects with a diameter:
   - (a) of three inches or less
   - (b) between three and four inches
   - (c) of more than four inches

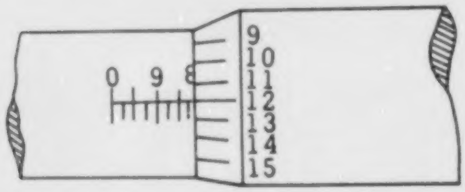
5. The reading on the illustrated three inch to 4 inch outside micrometer is:
   - (a) 3.157
   - (b) 3.467
   - (c) 3.187
   - (d) 3.012


0
1
15
14
13
12
11
10
9

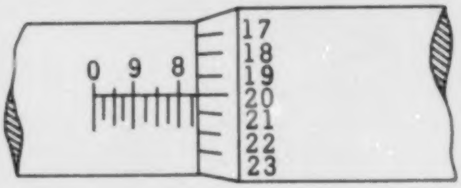
6. The reading on the illustrated three to four inch depth micrometer is:
   - (a) 3.812
   - (b) 3.982
   - (c) 3.892
   - (d) 3.875


0
9
8
9
10
11
12
13
14
15

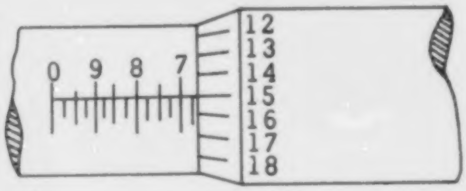
7. Find the following depth micrometer readings:


0
9
8
9
10
11
12
13
14
15

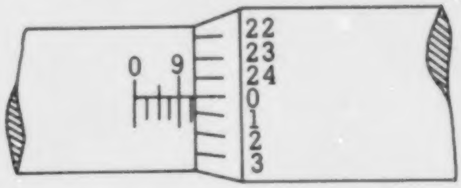
(a) ______________________


0
9
8
17
18
19
20
21
22
23

(b) ______________________

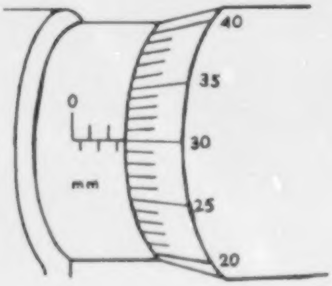

0
9
8
7
12
13
14
15
16
17
18

(c) ______________________

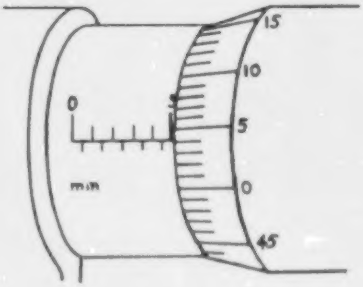

0
9
22
23
24
0
1
2
3

(d) ______________________

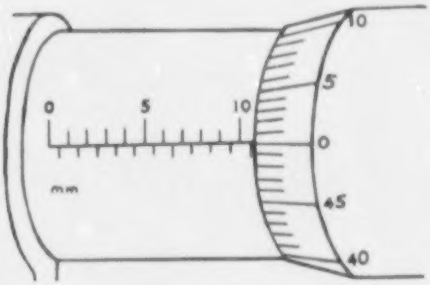
8. Find the following metric outside micrometer readings:


0
mm
40
35
30
25
20

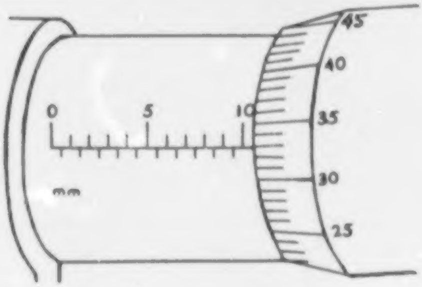
(a) ______________________


0
5
mm
15
10
5
0
45

(b) ______________________

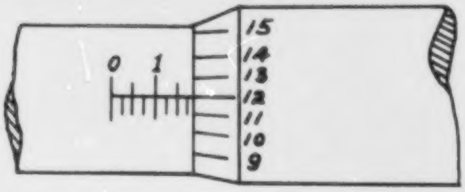

0
5
10
mm
10
5
0
45
40

(c) ______________________

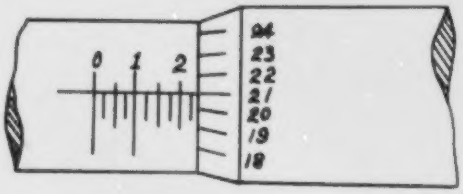

0
5
10
mm
45
40
35
30
25

(d) ______________________

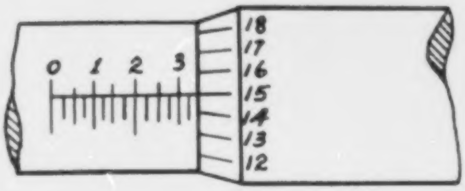
9. Find the following outside micrometer readings:


0
1
15
14
13
12
11
10
9

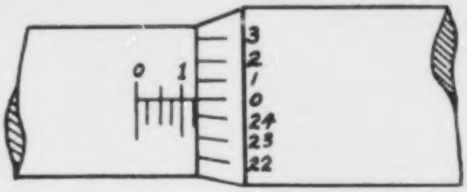
(a) ______________


0
1
2
24
23
22
21
20
19
18

(b) ______________

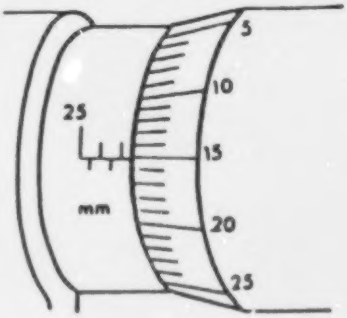

0
1
2
3
18
17
16
15
14
13
12

(c) ______________

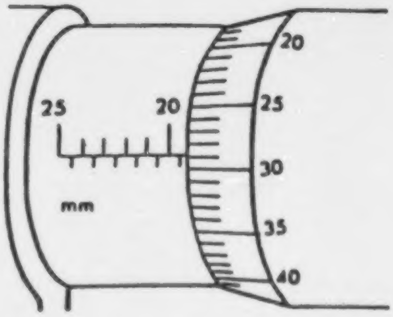

0
1
3
2
1
0
24
23
22

(d) ______________

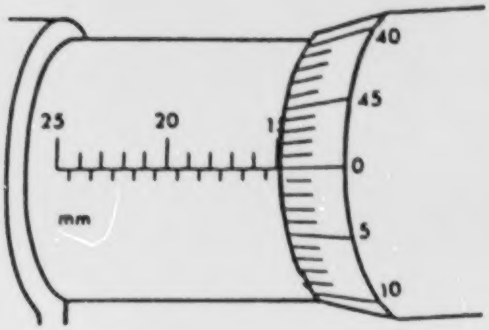
10. Find the following metric depth micrometer readings:


25
mm
5
10
15
20
25

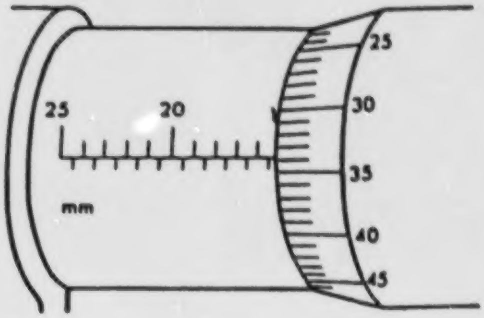
(a) ______________


25
20
mm
20
25
30
35
40

(b) ______________



(c)______________



(d)________________

11. Inside diameters can be measured with a:
    - (a) outside micrometer
    - (b) telescoping gauge and outside micrometer
    - (c) measuring hole gauge
    - (d) small hole gauge and ruler
12. A telescoping gauge is used for measuring the:
    - (a) circumference of a circular piece
    - (b) diameter of a hole
    - (c) thickness of a square piece
13. True or False? Feeler gauges can either be stepped or be the same thickness from heel to toe.
14. A stepped feeler gauge is often called a:
    - (a) shim
    - (b) round wire gauge
    - (c) go-no-go gauge
15. When standard feeler gauge blades become rough or bent they should be:
    - (a) straightened
    - (b) tapped gently with a soft face hammer
    - (c) replaced
    - (d) cut off to remove the damaged portion

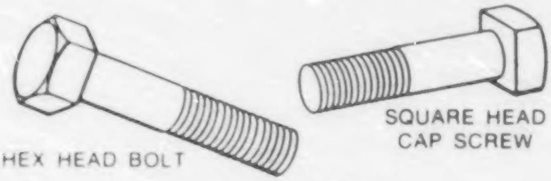
FASTENERS

There are many types of fasteners used in the mechanical field; a brief description of the common ones are given in this section.

BOLTS AND CAP SCREWS

General Information

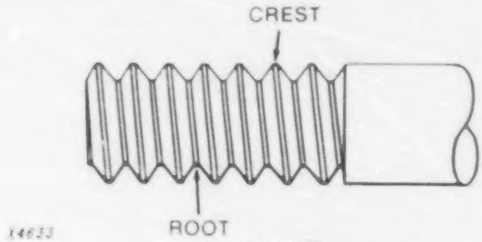
1. Bolts are held in place with a mating nut, while cap screws are generally used in threaded holes without a nut (Figure 1-112).



(1-112)

Courtesy of John Deere Ltd

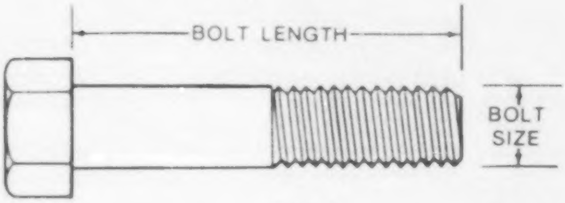
2. Bolt heads are either square or hexagonal (six-sided). Hex are most common.
3. The tops of threads are called crests, and the bottoms roots (Figure 1-113).



(1-113)

Courtesy of John Deere Ltd

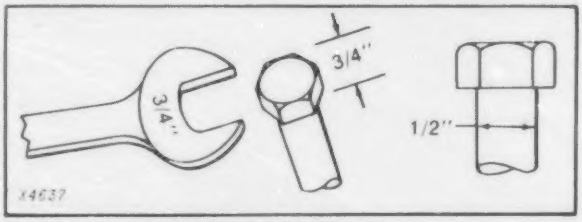
4. The size of a bolt is determined by the diameter of the crest of the threads (Figure 1-114). The length of a common bolt is determined by measuring from the bottom of the head to the end of the threads.



(1-114)

Courtesy of John Deere Ltd

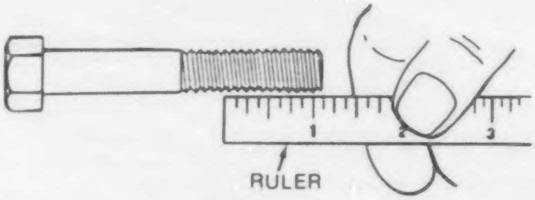
5. A bolt head is measured across the flats. Head size determines what size wrench or socket must be used to turn or hold the bolt. For example, a 3/4 inch wrench (Figure 1-115) is needed to turn a 1/2 inch bolt.



(1-115) BOLT HEAD SIZE

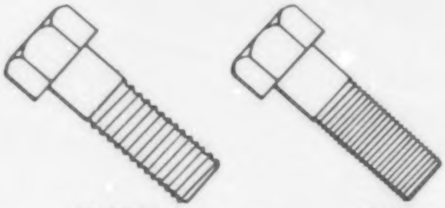
Courtesy of John Deere Ltd

6. Threads are measured by counting the number of threads per inch (thread pitch) (Figure 1-116). Thread pitch on metric bolts is given in millimeters and is defined as the distance from crest to crest. Threads are either course or fine (Figure 1-117). Course threads have deep grooves and are used for applications such as attaching accessories with nuts and bolts and threading into castings. Fine threads are used where coarse threads are not suitable, for example, when the parts being fastened have thin walls and when greater torque is required. Many internal engine parts are attached with fine threaded bolts and nuts.



(1-116) THREADS PER INCH

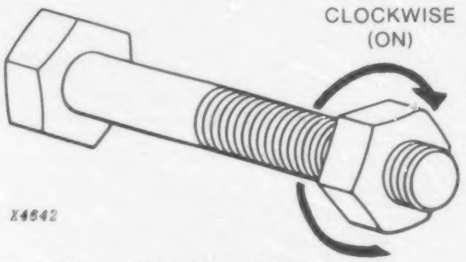
Courtesy of John Deere Ltd



(1-117)

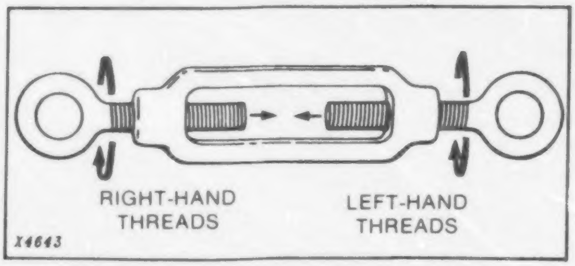
Courtesy of John Deere Ltd

7. Bolts and screws normally have right-hand threads; that is, they are turned to the right or clockwise when threaded into a nut or part (Figure 1-118). In a few rare cases, bolts, screws and nuts with left-hand threads are needed. Turnbuckles (Figure 1-119), for example, have one bolt with left-hand threads, and some wheel nuts have left-hand threads.


CLOCKWISE
(ON)
X4642

(1-118) RIGHT-HAND THREADS

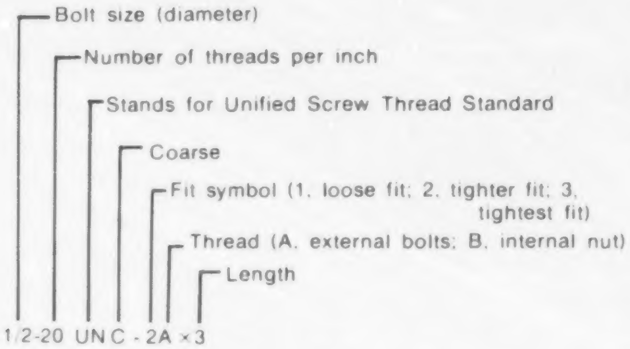
Courtesy of John Deere Ltd.


RIGHT-HAND
THREADS
LEFT-HAND
THREADS
X4643

(1-119) A TURNBUCKLE HAS BOTH RIGHT-HAND AND LEFT-HAND THREADS

Courtesy of John Deere Ltd.

8. The modern system for identifying bolts can be seen by looking at the following bolt size: 1/2-20 UN C - 2A × 3. The system is explained in Figure 1-120.


Bolt size (diameter)
Number of threads per inch
Stands for Unified Screw Thread Standard
Coarse
Fit symbol (1, loose fit; 2, tighter fit; 3, tightest fit)
Thread (A, external bolts; B, internal nut)
Length
1/2-20 UN C - 2A × 3

(1-120) BOLT IDENTIFICATION

Courtesy of John Deere Ltd.

Note that in the past, NC standing for National Course, and NF for National Fine were used to identify threads. The modern system of bolt identification has been used since 1948.

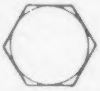
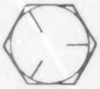
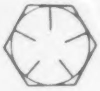
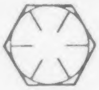
9. The Society of Automotive Engineers (SAE) has established certain standards for grading bolts and screws based on their material and treatment and on their tensile strength or as it's sometimes called, elastic limit. Tensile strength is the amount of pull bolts can stand without distorting or breaking. These standards are being accepted as international standards by the International Standard Organization (ISO). SAE designates markings (slashes) to be put on bolt and screw heads to indicate grades, and all high-quality bolts and screws of recent manufacture have them. The grade of a bolt is found by counting the number of slashes on the bolt and then adding two. For example, if a bolt has three slashes, it is a grade five bolt; if it has five slashes it's a grade seven.

The chart in Figure 1-121 identifies the various bolt grades and their characteristics. Most modern manufacturers are using Grade 5 or better bolts in their products. Even if grades lower than five are used in manufacture, grade 5 or higher is usually specified for replacement. Grade 8 and better are extensively used in heavy duty mechanics.

Types Of Bolts

Common bolts: the bolts discussed so far are referred to as common bolts.

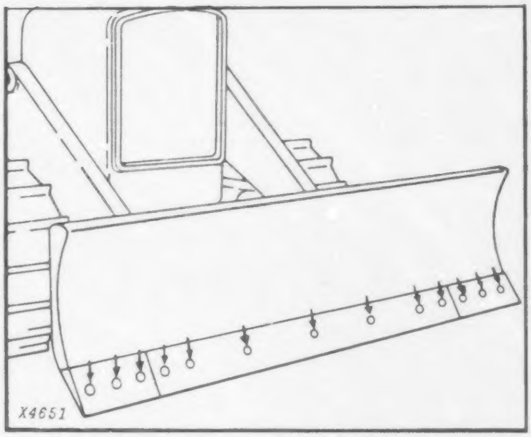
Plow bolts: used on plows and blades where the bolts must be flush with the mold board (Figure 1-122). They have flat tapered heads and fit into countersunk holes. There are three types of plow bolts identified by the numbers 3, 4 and 7 (Figure 1-123).

SAE GRADE MARKINGS FOR STEEL BOLTS AND SCREWS			
Grade Marking	Specification	Material	Tensile Strength min., psi.
	SAE-Grade 0	Steel	
	SAE-Grade 1	Low Carbon Steel	55,000
	SAE-Grade 2	Low Carbon Steel	69,000*
	SAE-Grade 5	Medium Carbon Steel, Quenched and Tempered	120,000*
	SAE-Grade 7	Medium Carbon Steel, Quenched and Tempered	133,000
	SAE-Grade 8	Medium Carbon Alloy Steel, Quenched and Tempered	150,000

*Small size bolts. Larger bolts may have lower values X4646

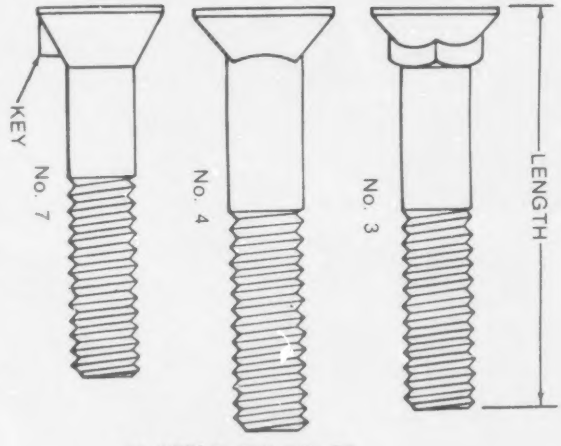
(1-121) SAE GRADE MARKINGS AND STRENGTH SPECIFICATIONS

Courtesy of John Deere Ltd.



(1-122) PLOW BOLTS ON DOZER BLADE

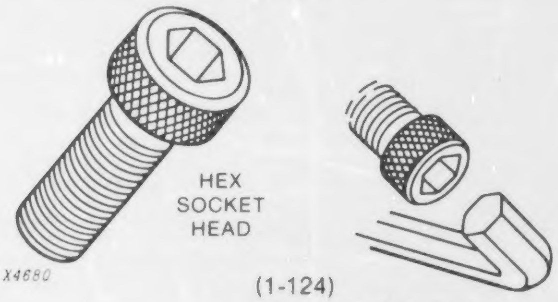
Courtesy of John Deere Ltd.



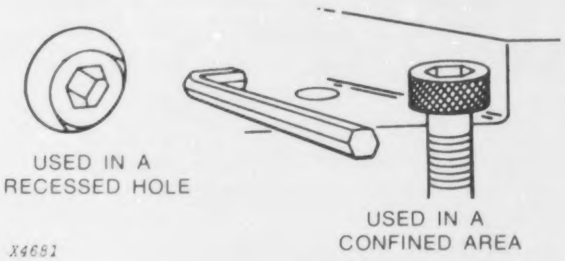
(1-123) PLOW BOLTS

Courtesy of John Deere Ltd.

Hex socket head bolts: sometimes used in recessed (sunken) holes (Figure 1-124) or in confined spaces where the small head size is an advantage. Its head has a hexhole for a hex (Allen) wrench. These bolts are available in UNC and UNF.

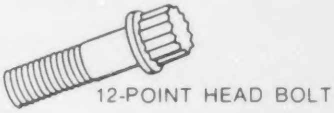


(1-124)
Courtesy of John Deere Ltd.



(1-124) HEX SOCKET HEAD, BOLT
Courtesy of John Deere Ltd.

12-point head bolts: used when high strength bolts with small heads are required (Figure 1-125). They are turned by a small double hex socket or a 12-point box-end wrench.



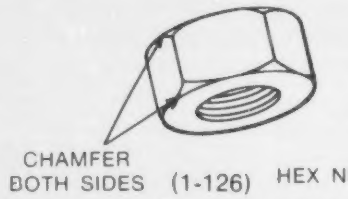
(1-125) Courtesy of John Deere Ltd

NUTS

There are literally hundreds of nuts of all shapes and sizes. The nuts discussed here are the ones you are most likely to encounter. Nuts have three important dimensions: (1) thickness, (2) distance across flats, and (3) inside diameter (ID). Note that the ID of a nut is the same as the OD of its mating bolt.

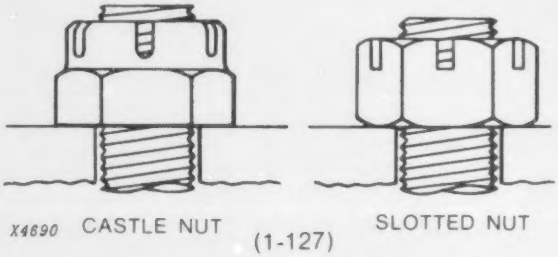
Types Of Nuts

Hex nuts: the most common nuts are made of steel and are hexagonal or square. Most hex nuts have chamfered (beveled) corners on both sides (Figure 1-126) so that they can be installed with either side down.

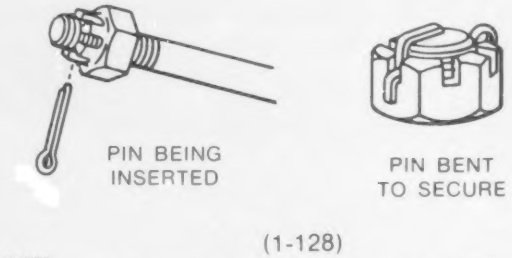


(1-126) HEX NUT
Courtesy of John Deere Ltd.

Castle nuts and slotted nuts: the top part of a castle nut is smaller in diameter than the body of the nut. (It should be noted that castle nuts are no longer recommended for new machinery.) A slotted nut is simply a hex nut with slots (Figure 1-127). Both nuts are mated with bolts having a hole drilled through the end. When the nut is tightened a cotter pin (Figure 1-128) is inserted through the slots and hole to hold the nut firmly in place. Steering parts are often secured with slotted nuts.



(1-127)
Courtesy of John Deere Ltd.



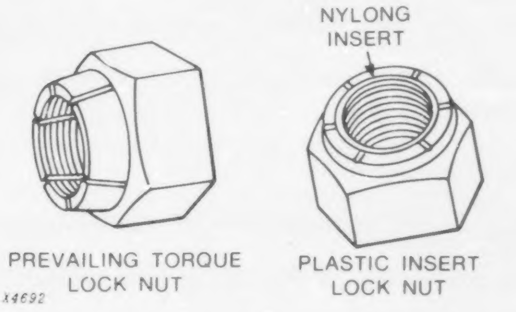
(1-128)
A COTTER PIN SECURES A CASTLE OR SLOTTED NUT
Courtesy of John Deere Ltd.

Self locking nuts: once tightened stay firmly in place. There are many types of self locking nuts, having many ingenious means of staying tight. The most common ones are called prevailing-torque nuts and plastic-insert nuts (often referred to by their trade name Elastic nuts).

A prevailing-torque nut has a means of gripping the mating threads. One popular prevailing-torque nut (Figure 1-129) resembles a castle nut — the top is split into sectors bent inward. When the nut is threaded onto a bolt, the sectors are forced outward and tightly grip the bolt. Prevailing-torque nuts can be reused.

Plastic insert nuts (Figure 1-129) which are actually a special type of prevailing-torque nut, contain a relatively soft collar of unthreaded material built into the head. This collar may be a fibrous material or a plastic such as nylon. When the nut is threaded onto a bolt, threads are impressed into the collar. Being elastic, the collar has a tendency to return to its original shape when the nut is removed. Although plastic insert nuts can be reused, it is usually recommended that they be replaced.

Interference nuts are similar to plastic insert nuts except that the top two threads are bent in slightly in a few places giving an interference that prevents the nut from coming loose. Once removed these nuts are replaced.



PREVAILING TORQUE LOCK NUT

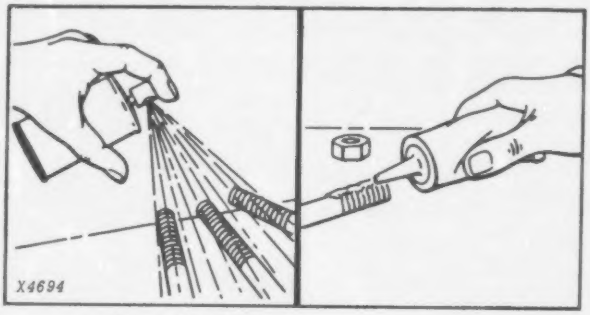
PLASTIC INSERT LOCK NUT

(1-129) PREVAILING-TORQUE AND INSERT-TYPE SELF-LOCKING NUTS

Courtesy of John Deere Ltd.

Another feature of self-locking nuts is a good ability to seal out moisture.

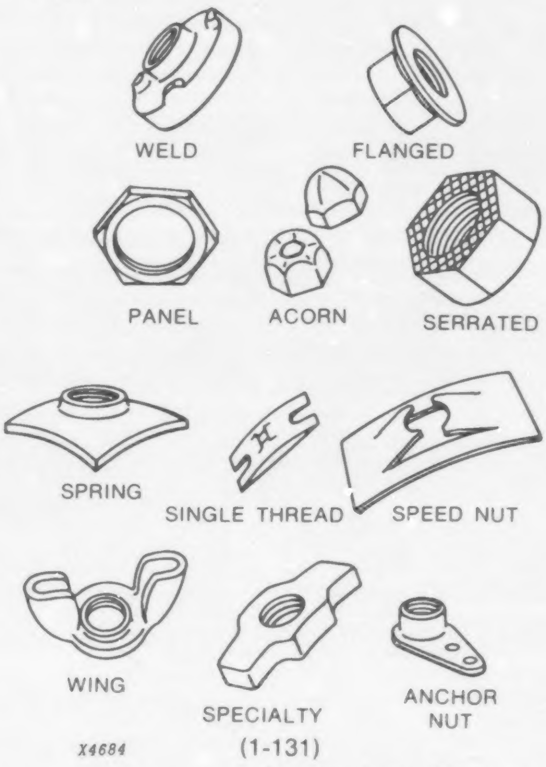
Chemical lock for nuts: regular nuts can be locked with a liquid lock (Loctite, for instance) to prevent loosening, especially from vibration. Most chemical locks (Figure 1-120) are free-flowing plastic material. When applied to threads, the chemical will fill the spaces between the threads and harden. For critical applications a primer can be sprayed on the threads to clean them and speed up the drying time of the chemical lock. Chemical locks are excellent for keeping nuts and bolts tight, and have the advantage that the bond can be broken, if necessary, to remove the nut.



(1-130) SEALANTS AND PRIMERS FOR NUTS AND BOLTS

Courtesy of John Deere Ltd.

Miscellaneous nuts: are illustrated in Figure 1-131.

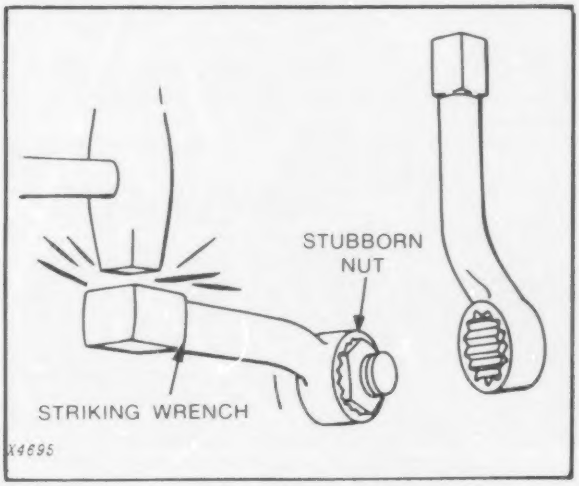


(1-131)

Courtesy of John Deere Ltd.

Removing Stubborn Nuts

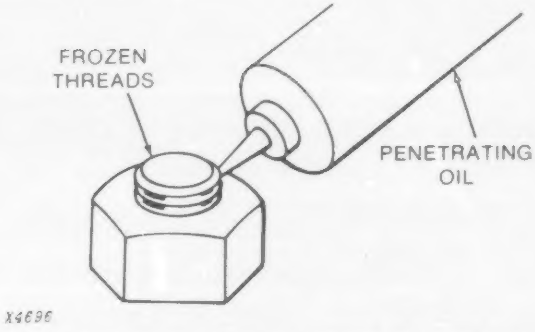
Sometimes, due to dirt, rust, or other corrosion, nuts are very difficult to remove. Some shops have a power impact wrench that can be used to loosen tough nuts. If an impact wrench isn't available, and the location of the nut permits, try a striking wrench as shown in Figure 1-132.


STUBBORN NUT
STRIKING WRENCH
X4695

(1-132) USING A STRIKING WRENCH TO REMOVE A STUBBORN NUT

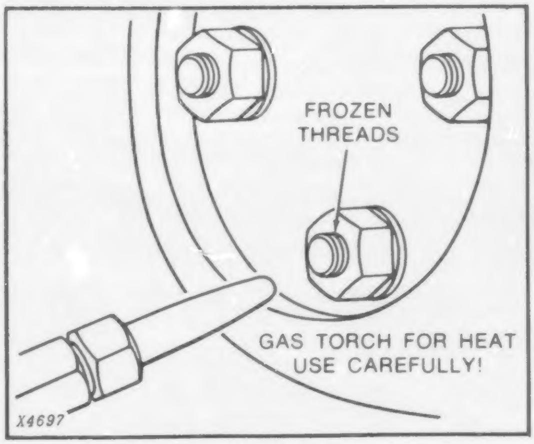
Courtesy of John Deere Ltd

Sometimes hard-to-remove nuts can be loosened with penetrating oil (Figure 1-133) or special liquids made for this purpose. Heat can also be used, and is usually the quickest (Figure 1-134). However, heat must be used with caution in areas where it could damage other parts.


FROZEN THREADS
PENETRATING OIL
X4696

(1-133) PENETRATING OIL IS OFTEN HELPFUL IN REMOVING NUTS

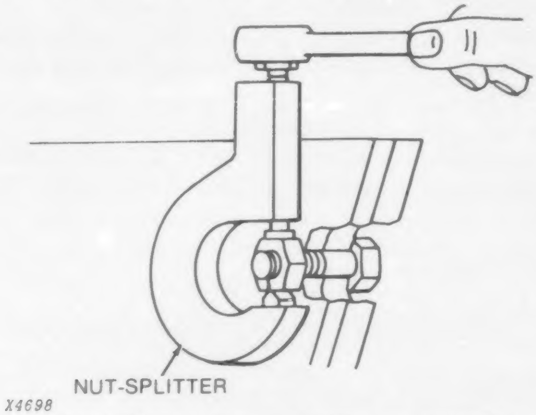
Courtesy of John Deere Ltd


FROZEN THREADS
GAS TORCH FOR HEAT USE CAREFULLY!
X4697

(1-134)
HEAT IS OFTEN HELPFUL BUT USE IT WISELY

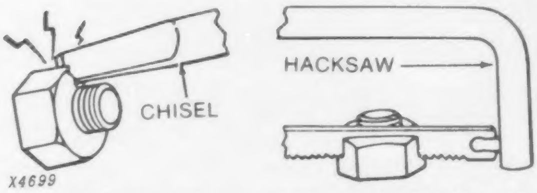
Courtesy of John Deere Ltd.

In many cases, because of the high cost of labor, stubborn nuts and bolts are cut off with a cutting torch and the bolts and nuts are replaced. If a torch isn't available stubborn nuts can be cracked off with a nut splitter (Figure 1-135). If all else fails, use a sharp chisel or hacksaw (Figure 1-136), but take care not to damage other parts.


NUT-SPLITTER
X4698

(1-135) USING A NUT SPLITTER TO REMOVE A STUBBORN NUT

Courtesy of John Deere Ltd

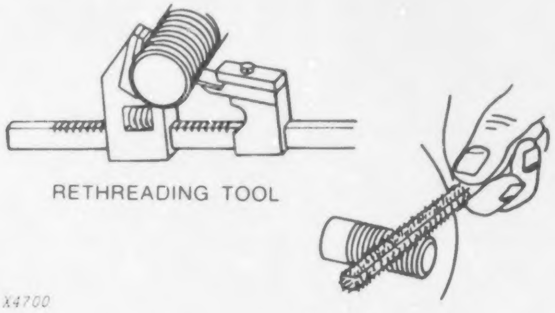

HACKSAW
CHISEL
X4699

(1-136) USING A CHISEL OR HACKSAW TO REMOVE A NUT

Courtesy of John Deere Ltd

RESTORING THREADS

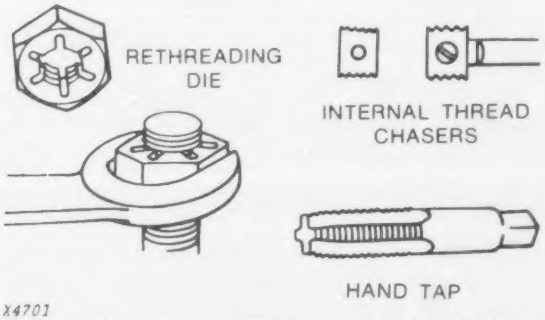
Even though you try to be careful, sometimes threads may be damaged. If a replacement isn't available, threads may be touched up with a rethreading tool or a thread file (thread chaser) (Figure 1-137).



(1-137) USING A RETHREADING TOOL AND THREAD RESTORER

Courtesy of John Deere Ltd.

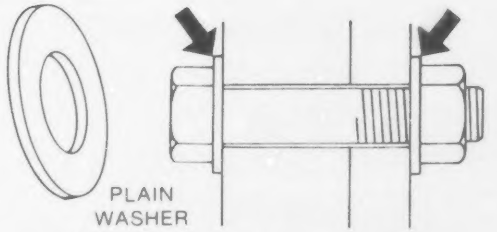
Another means of cleaning or restoring bolt and stud threads is a rethreading die or die nut available in kits of both UNC and UNF thread from 1/4'' to 1'' (Figure 1-138). Internal holes can be recut with an internal thread chaser or hand tap, although regular taps are generally used.



(1-138) OTHER THREAD-RESTORING TOOLS

Courtesy of John Deere Ltd.

WASHERS



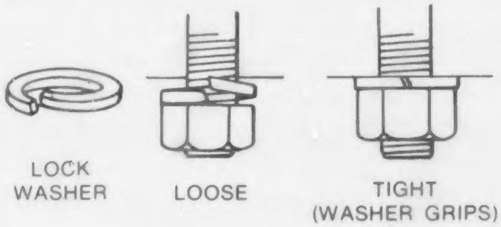
(1-139) A FLAT STEEL WASHER

Courtesy of John Deere Ltd.

Plain washers: are steel discs with a hole through the center (Figure 1-139). Though simple parts, washers are very important in many applications. When used under the head of a bolt or under a nut, a plain washer distributes the load and thus the stress over an area larger than the head of the bolt or nut. Washers also protect surfaces from being damaged by bolt heads or nuts.

Plain washers are identified by the bolt size of their inside diameter and by their outside diameter. The inside diameter is a little oversized (about 1/32 of an inch) so that the washer will slide easily over the bolt. Washers come in various thicknesses; they are made of mild steel for general use, and hardened steel for locations such as under cylinder head nuts. Hardened steel washers are designated by a part number.

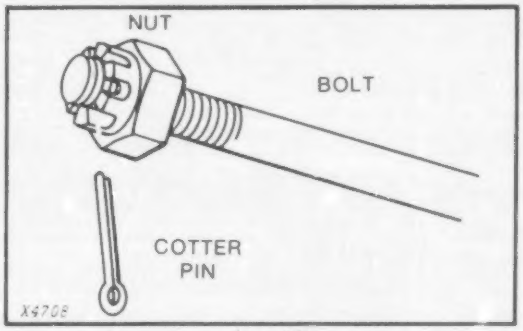
Split-ring lock washers: are frequently used to keep nuts and bolts tight, especially when they are subject to machine vibration (Figure 1-140). When the nut or bolt is tightened, the ends of the washer bite into the nut or bolt head and into the fastened part, helping to keep the nut or bolt from turning. Lock washers are identified by bolt sizes except for ones under one-quarter inch which are identified by numbers.



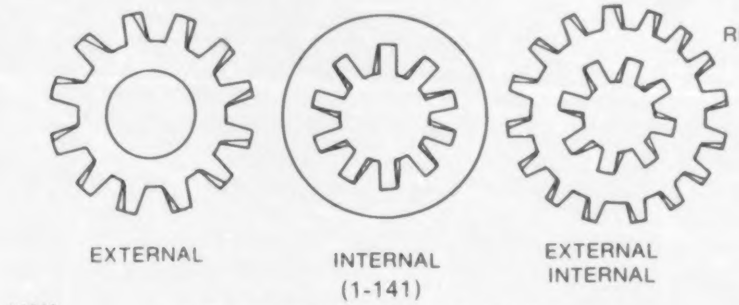
(1-140)

Courtesy of John Deere Ltd.

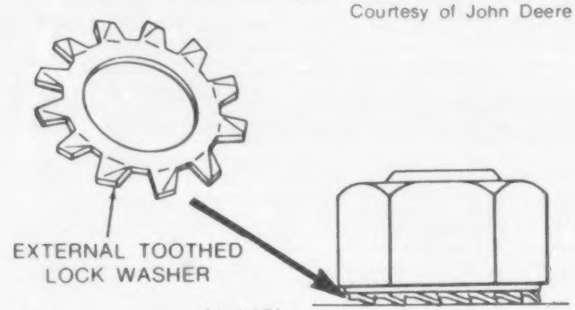
Tooth lock washers: are used when special holding power is required because they have many sharp, heat-treated teeth to dig into contacting surfaces (Figure 1-141). Tooth washers are identified by bolt sizes except for ones under one-quarter inch which are identified by numbers. Often known by their trade name, Shakeproof, they may have outside or inside teeth, or have both outside and inside teeth for extra holding ability (Figure 1-142). Cone-shaped tooth washers are made for use with countersunk, flat-head screws.


NUT
BOLT
COTTER PIN
X4708

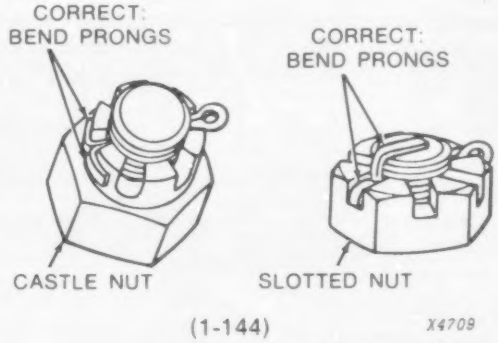
(1-143)
RELATION BETWEEN A COTTER PIN, NUT, AND BOLT
Courtesy of John Deere Ltd.


EXTERNAL
INTERNAL
EXTERNAL INTERNAL
X4706

(1-141)
TOOTHED LOCK WASHER STYLES
Courtesy of John Deere Ltd.


EXTERNAL TOOTHED LOCK WASHER
X4705

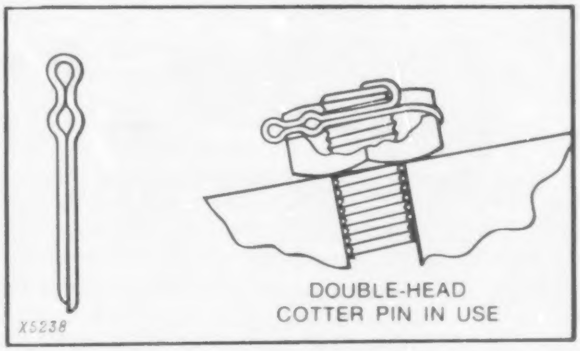
(1-142)
HOW A TOOTHED LOCK WASHER GRIPS
Courtesy of John Deere Ltd.


CORRECT: BEND PRONGS
CORRECT: BEND PRONGS
CASTLE NUT
SLOTTED NUT
X4709

(1-144)
Courtesy of John Deere Ltd.

COTTER PINS

Cotter pins hold a nut and bolt tightly together and keep the nut from coming off. Cotter pins are slipped between the nut slots and through a hole in the end of the bolt (Figure 1-143). They are made of soft metal so that the prongs can be bent around the nut. Note that when tightening a nut and the hole in the bolt does not line up with the nut slots, the nut must be tightened just enough so that the pin can be inserted. Never loosen a nut to align the cotter slot unless manufacturer's instructions say so. Some bolts may have two holes for more precise adjustment. Cotter pin installation is illustrated in Figures 1-144 and 1-145.


DOUBLE-HEAD COTTER PIN IN USE
X5238

(1-145)
Courtesy of John Deere Ltd.

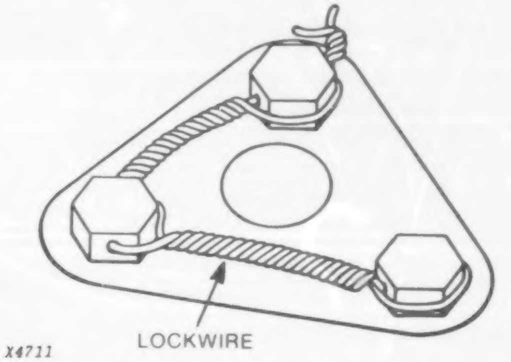
LOCKWIRES

Sometimes lock or safety wire are used to anchor bolts in place. The bolts have holes drilled through their heads. The lockwire is pushed through the bolt holes (Figure 1-146) and twisted in such a way that the wire will tighten if a bolt loosens.

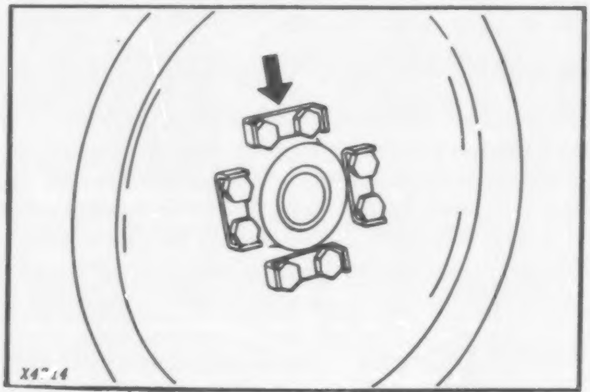
Occasionally it is important to prevent unauthorized tampering with critical mechanisms or adjustments. In such a case a seal is attached to the lockwire as it is twisted; the seal must be broken before the lockwire can be removed. A special sealing tool is used to close the seal after it is installed on the lockwire. The diesel fuel injection pump on a modern tractor is an example where a lockwire and seal are used.

FLAT METAL LOCKS

Another way of locking bolts or nuts to keep them from turning is with flat metal locks (Figures 1-147 and 1-148). These are usually made of soft metal, although some are hardened. Some have special shapes for specific applications. Flat metal locks must be installed properly to be effective. Bend one end of the lock sharply around the edge of the part (Figure 1-147). Bend the other end sharply against one flat surface of the nut or capscrew head. Do not bend the lock against more than one side of the nut.

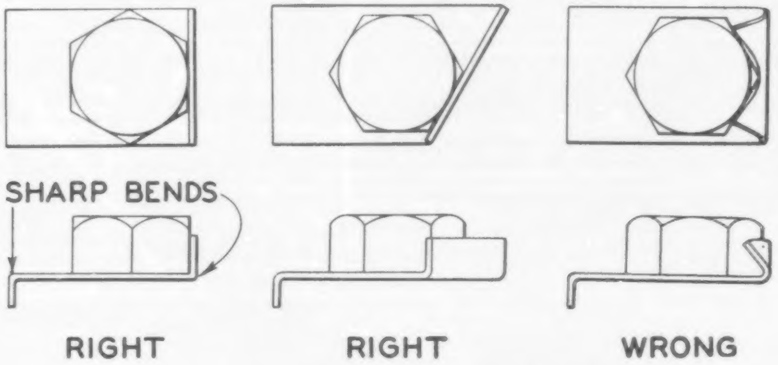


(1-146) Courtesy of John Deere Ltd



(1-148) FLAT METAL LOCKS HOLD FLYWHEEL BOLTS IN PLACE

Courtesy of John Deere Ltd

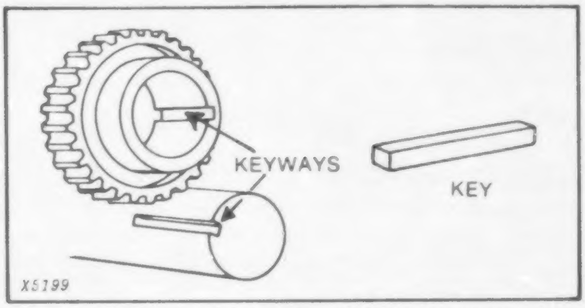


(1-147) HOW TO INSTALL FLAT METAL LOCKS

Courtesy of Caterpillar Tractor Company

KEYS

One very common way of holding a gear, pulley or other part to a shaft is by means of a key (Figure 1-149). In some ways the name is misleading because these fasteners do not look like keys in the usual sense. Most are simple lengths of steel cut from square or rectangular stock, or are round stock cut in half. The gear or other part, and the shaft have grooves cut into them called keyways. In most cases the key is placed into the shaft keyway, and the gear is pressed onto the shaft over the key.



(1-149) A KEY AND THE KEYWAYS IN A GEAR AND SHAFT

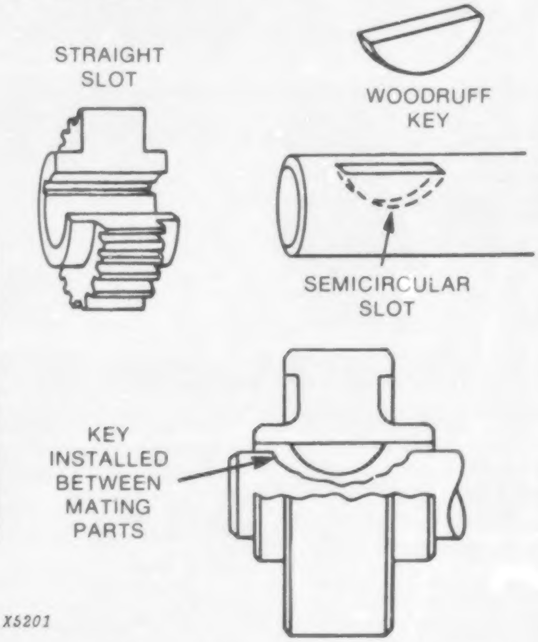
Courtesy of John Deere Ltd.

Woodruff Key

A semicircular key made from round stock cut in half (like a half moon) is called a Woodruff key. This key is used to lock a shaft and gear in one position, rather than simply to anchor a gear onto a shaft (Figure 1-150). In some applications a straight, square key has a tendency to rock because it cannot be sunk deeply enough into the shaft. In such a case a Woodruff key is used because its keyway is much deeper than an ordinary one. Woodruff keys have two dimensions, diameter (or length) and thickness, and come in many sizes.

For a Woodruff key, a semicircular keyway is cut in the shaft. The gear to be mated to the shaft has a straight slot cut on it (Figure 1-150). The Woodruff key is placed in the curved slot in the shaft and projects above the shaft far enough to fill the gear slot. The gear is then driven or pressed onto the shaft.

Installing and removing key-held parts such as gears requires special care, and often special tools, since these parts usually fit on their shafts very tightly. Always follow the instructions of the manufacturer. Using hammers, pry bars and chains to remove a stubborn gear or other key-held part will likely damage the part. Special pullers that fit the parts and apply force evenly are often the answer, or a shop press if the parts can be taken to the press.

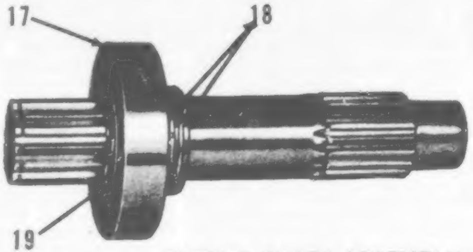


(1-150) HOW A WOODRUFF KEY IS USED

Courtesy of John Deere Ltd.

SPLINES

Splines are similar to keys and keyways except rather than having one keyway in the shaft there are a number of keyways called splines. The splines are cut lengthwise into the shaft, and are evenly spaced around the shaft. The part that fits on the shaft has an equal number of matching splines around its inner diameter. The part may be a sliding fit on the shaft or a press fit, depending on its application. Figure 1-151 shows a typical splined shaft.



OUTPUT SHAFT ASSEMBLY

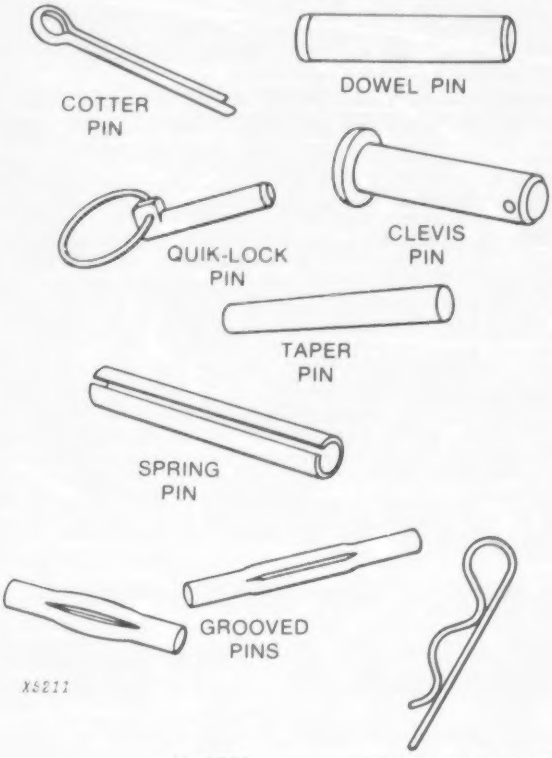
17—Bearing. 18—Piston ring seals. 19—Snap ring.

(1-151) CATERPILLAR

Courtesy of Caterpillar Tractor Company

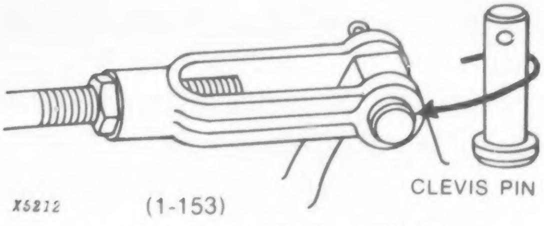
PINS

Some common pins are illustrated in Figure 1-152.


COTTER PIN
DOWEL PIN
CLEVIS PIN
QUIK-LOCK PIN
TAPER PIN
SPRING PIN
GROOVED PINS
SPRING LOCKING PIN
X5211

(1-152)
SOME FREQUENTLY USED PINS
Courtesy of John Deere Ltd.

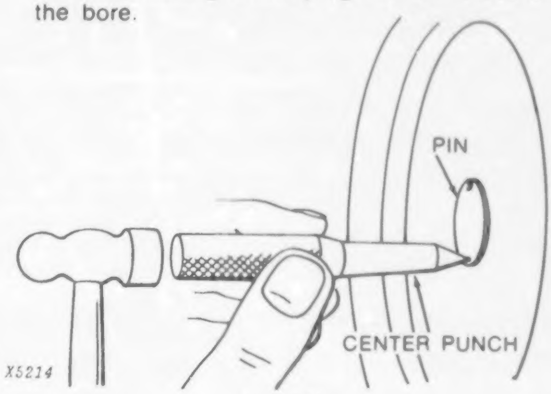
Clevis or Headed pins: the simplest pin is a headed pin, often called a clevis pin because it is used to attach a part to a U-shaped yoke known as a clevis (Figure 1-153). Headed pins are usually drilled on the end opposite the head for insertion of a cotter pin, a quik-lock pin or a spring-lock pin.


CLEVIS PIN
X5212

(1-153)
A CLEVIS PIN USED TO ATTACH
A TURNBUCKLE
Courtesy of John Deere Ltd.

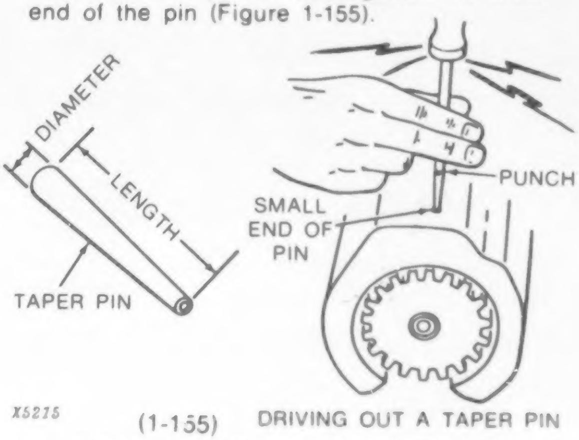
Pivot pins: serve as small axles for parts to pivot on. The pivots for governor flyweights are a good example. Pivot pins are usually headless and are drilled or grooved for cotter pins or snap rings.

Pivot pins are often tight in their holes. When tight-fitting pins are removed, they must be driven out with a hammer and a pin punch that's nearly the size of the pin. Pivot pins are often staked in place (Figure 1-154) so that they won't fall out. A small center punch is used for this purpose. The center punch, when struck with a hammer, slightly flairs the end of the pin pressing it firmly against the sides of the bore.


PIN
CENTER PUNCH
X5214

(1-154)
STAKING A PIN TO HOLD IT IN PLACE
Courtesy of John Deere Ltd.

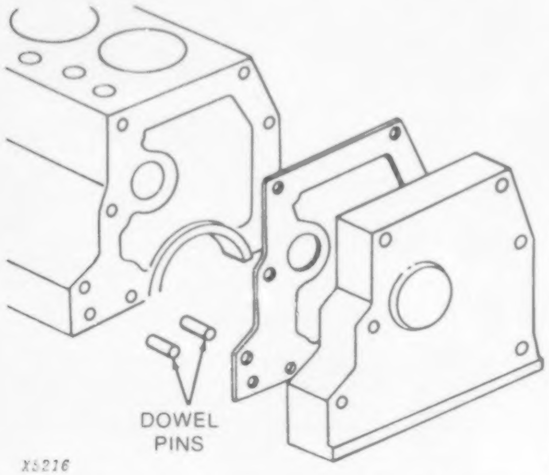
Taper pins: parts that must fit tightly are often fastened together with a taper pin (Figure 1-155). The taper on the pin helps to line up the holes in the parts being assembled. The pin is driven into a specially reamed hole until it is fully seated. Taper pins are driven out with a hammer and a punch held against the small end of the pin (Figure 1-155).


DIAMETER
LENGTH
TAPER PIN
PUNCH
SMALL END OF PIN
X5215
DRIVING OUT A TAPER PIN

(1-155)
A TAPER PIN AND HOW IT IS REMOVED
Courtesy of John Deere Ltd.

Dowel pins: are frequently used to assure that fastened parts align exactly as they are supposed to. The dowel pins that line up the timing gear cover and gasket with the engine crankcase are a good example (Figure 1-156).

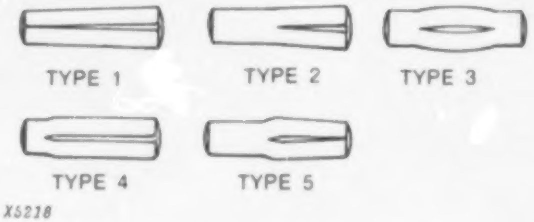
A dowel pin is a tiny bit larger in diameter than the hole into which it is to go, and so it must be pressed or driven in. Once in place the press-fit assures that the pin will not come out. The outer end of a dowel pin projects above the surface of the part into which it is pressed and mates with other holes in the adjoining parts. Dowel pins are usually permanent and need not be replaced unless they are damaged.



(1-156) HOW DOWEL PINS LINE UP PARTS FOR EASY ASSEMBLY
Courtesy of John Deere Ltd.

Spring pins: often called roll pins, are hollow cylinders of spring steel (Figure 1-152). They are split lengthwise and beveled at each end for easy starting. They are used in areas where loads are not too great. Spring pins are made slightly oversize so that when they are driven or pressed into place, they are compressed. It is this tension that holds the parts in place. To remove a spring pin, drive it out of its hole with a punch just a little smaller in diameter than the hole.

Grooved pins: are solid, having slots or grooves cut along all or part of their length (Figure 1-157). Their holding power comes from a tendency to expand when driven into place. Grooved pins come in standard types. In the past the type designations were letters A, B, C, etc. but now numbers are used: Type 1, Type 2, etc.

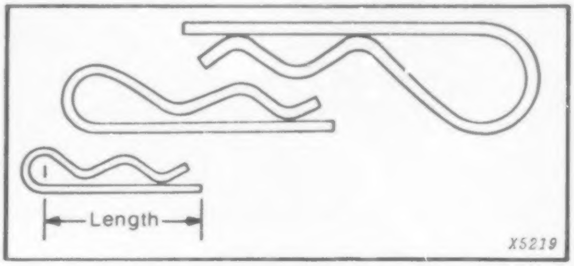


(1-157) TYPES OF GROOVED PINS
Courtesy of John Deere Ltd.

Convenience Pins

Several types of pins are made for quick and easy removal, e.g., spring locking pins and quik-lock pins.

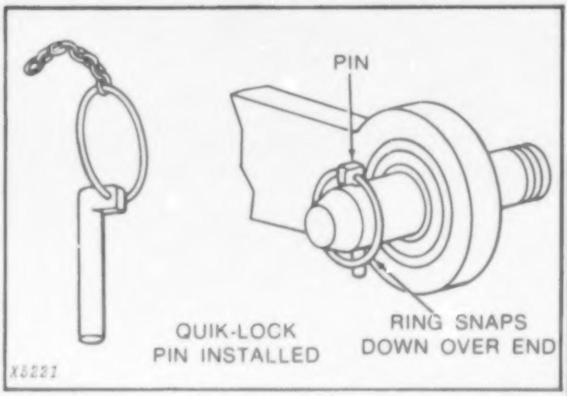
Spring locking pins: often called a hairpin cotter (Figure 1-158), is used when parts must be separated for adjusting or for changing replaceable parts. Usually a spring locking pin is inserted into a hole drilled through a clevis pin to hold the parts together.



(1-158) TYPICAL SPRING LOCKING PINS
Courtesy of John Deere Ltd.

Quik-Lock pins: (Figure 1-159) are another handy convenience pin. A common use of these pins is to fasten removeable attachments to a machine such as three-point hitch parts to a loader-backhoe.

Quik-lock pins have a split steel ring. The ends of the ring fit into two holes drilled in different planes in the pin head. Once the pin is in place, the steel ring is rotated down and around the end of the clevis pin (Figure 1-159). The difference in the two planes of the ring ends develops an over-center spring action which holds the ring firmly around the clevis pin holding the quik-lock pin in place. Some quik-lock pins have a short chain which can be fastened to a convenient nearby part to keep the pin from getting lost.

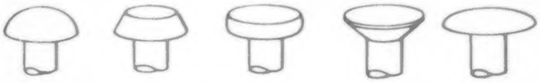


(1-159) QUIK-LOCK PIN PROPERLY INSTALLED
Courtesy of John Deere Ltd.

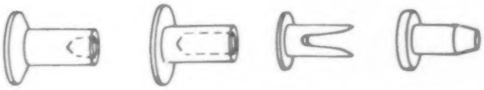
Shear pins: sometimes it is important that a pin be just strong enough to carry the normal load imposed upon parts. Such a pin is called a shear pin. The pin is made of a softer metal than the shaft and part it aligns. It acts as a safety device and will shear, or be cut off, when the parts are overloaded, preventing more serious damage to the machine. A shear pin is used for example on an outboard motor propeller.

RIVETS

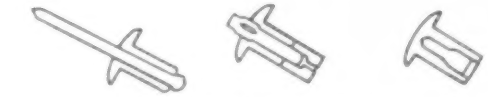
Rivets are soft metal pins with a head on one end. Some common rivets are shown in Figure 1-160.



IRON RIVETS



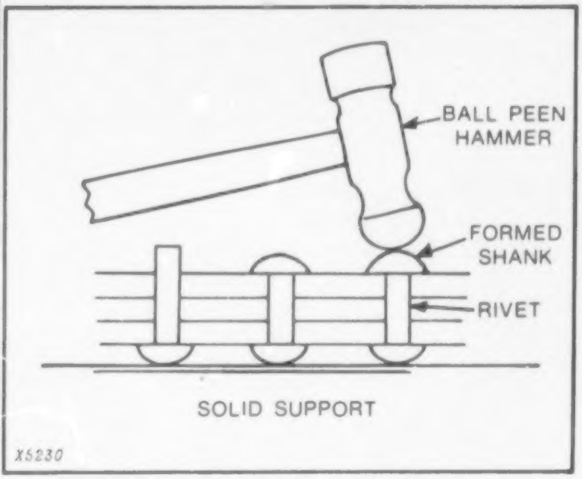
TUBULAR, SPLIT AND COMPRESSION RIVETS



BLIND RIVETS

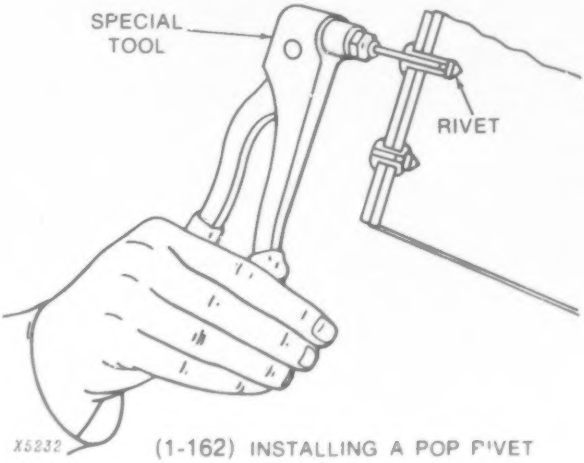
(1-160) RIVETS
Courtesy of John Deere Ltd.

Common iron rivets are used primarily to hold two or more flat, parallel parts together. The parts are drilled or punched, a rivet is inserted into the matching holes (Figure 1-161), and a second head is formed on the other end of the rivet (the shank) with a ball peen hammer or a riveting machine. When hammering the second head, the first rivet head must be pressed against something solid, otherwise the second head will not be formed properly.



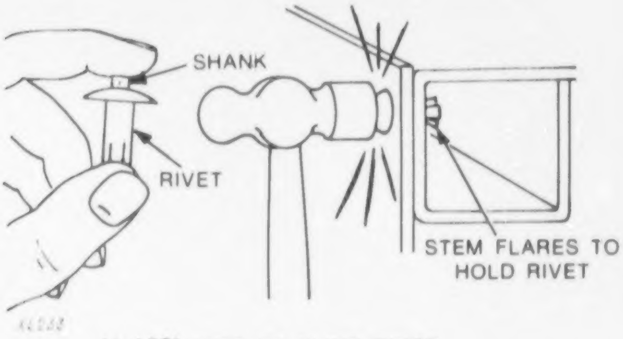
(1-161) PEENING THE SECOND HEAD OF A RIVET
Courtesy of John Deere Ltd.

Blind rivets: are intended for light duty use where the joint is accessible from only one side (the other side is blind). One common type (Figure 1-162) known as a pop rivet requires a special tool to install it. After the rivet is inserted, the tool pulls a stem with a bulb on the end up through the hollow center. The bulb causes the blind end of the rivet to flair, thus securing the rivet. The stem is then broken off.



(1-162) INSTALLING A POP RIVET
Courtesy of John Deere Ltd.

Another type of blind rivet also has a stem, but instead of pulling on it, the stem is driven into the rivet (Figure 1-163). The stem flares the lower end of the rivet to hold it firmly in place.

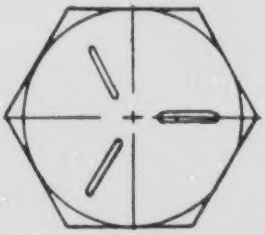

SHANK
RIVET
STEM FLARES TO HOLD RIVET

(1-163) TYPE OF BLIND RIVET

Courtesy of John Deere Ltd

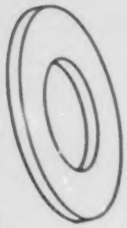
QUESTIONS — FASTENERS

1. Bolt head markings are usually:
   - (a) slash marks
   - (b) letters
   - (c) dots
   - (d) numbers
2. How is the length of a bolt determined?
3. Thread size refers to the:
   - (a) number of threads per inch
   - (b) length of the threaded part
   - (c) diameter of the bolt or screw
4. A threaded pitch refers to the:
   - (a) diameter of the bolt or screw
   - (b) number of threads per inch
   - (c) length of the threaded part
5. The marking on the head of the illustrated bolt indicates the __________ of the bolt:
   - (a) size
   - (b) length
   - (c) the grade
   - (d) thread type



6. What grade is the bolt in question 5?
7. The screw pitch gauge is used to determine:
   - (a) the depth of the thread in inches
   - (b) the length of the thread in inches
   - (c) the number of threads per inch
   - (d) the lead of the thread per inch
8. Hex, square, and castle are terms used to refer to different types of:
   - (a) screws
   - (b) bolts
   - (c) nuts
9. Hex head, phillips, and allen are terms used to describe different types of:
   - (a) screw threads
   - (b) studs
   - (c) screws
10. A castle nut requires:
    - (a) a lockwasher
    - (b) a jamnut
    - (c) a flatwasher
    - (d) a cotter pin
11. True or False? The cap screw has fine thread on one end and coarse thread on the other.
12. To determine the wrench size a bolt is measured:
    - (a) across the shank
    - (b) across the points on the head
    - (c) across the flats on the head

13. Match the numbered illustrations to their name: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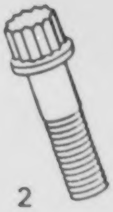
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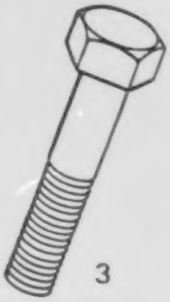
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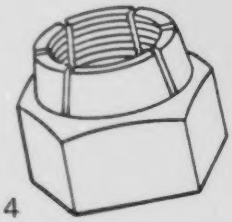
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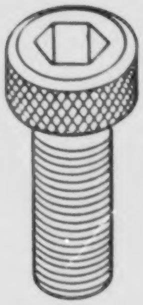
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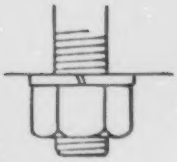
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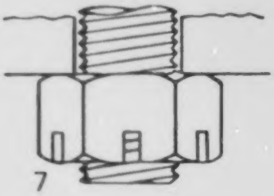
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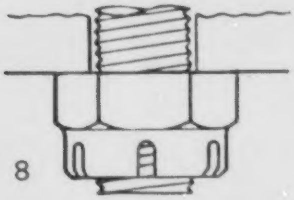
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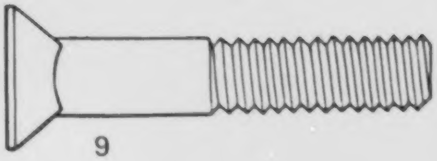
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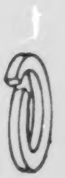

10

hex head bolt ____________

plow bolt ____________

hex socket head ____________

12-point head bolt ____________

hex nut ____________

castle nut ____________

lock washer ____________

lock nut ____________

flat washer ____________

slotted nut ____________

14. Name three ways of removing stubborn nuts.

15. What is the advantage of a Woodruff key over a straight key?

16. True or False? When a bolt has been tightened and the bolt hole does not quite line up with the nut slots, slightly loosen the nut so that you can insert the cotter pin.

17. True or False? To properly secure a nut with a flat metal lock, try to bend the lock against two flats of the nut head.

HOSES, PIPES, TUBES, FITTINGS AND ADAPTERS

HOSE

Flexible hoses with reusable fittings are one of the most important parts that require replacement on modern machinery. Hoses and fittings are used for diesel fuel, lube oil, air and water lines. They are also used on most hydraulic systems, having the advantages that they allow for motion, absorb vibration and noise, withstand pressure surges, and are easy to route and connect.

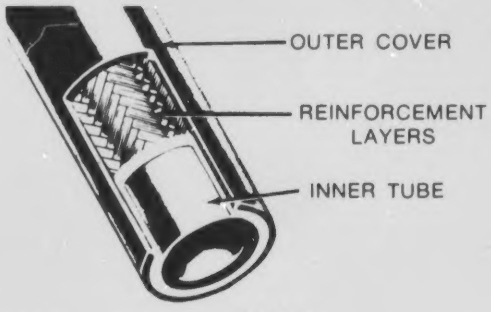
Hoses are available in low, medium, high and very high pressure ratings. Hose sizes and pressure ratings are generally stamped on the outer cover. Another way of identifying hose is by its dash number. The dash number represents the inside diameter of the hose in sixteenths of an inch. For example, a half inch hose has a dash number of 8, meaning an inside diameter of 8/16ths or 1/2 inch.

Some hoses on machines are replaced by cutting bulk hose to the required length and then attaching to it either the old fittings or new ones. Others are assembled hoses with crimped on fittings and must be ordered from the manufacturer.

Figure 1-164 shows a cutaway view of a flexible hose with typical screw-type replaceable fittings. Coarse, left-hand threads on the inside of the socket (2) grip the hose's outer cover as the hose is turned into the socket. A recess in the end of the socket permits the insertion of the tapered end of the nipple into the socket so that the fine threads on the nipple can engage with the matching threads in the end of the socket. As the nipple is threaded into the socket, it forcefully squeezes the inner liner and other layers of the hose out against the socket. Once assembled properly, the fitting requires no tightening or adjusting.

Hose Construction

Flexible hose has three basic parts: an inner tube, reinforcement layers, and an outer cover (Figure 1-165). The inner tube is an oil resistant synthetic rubber layer. It must be smooth, flexible, and able to resist heat and corrosion. The reinforcement layers vary with the type of hose and pressure requirement of the system. The layers (or plies) are constructed of natural or synthetic fibers, braided wire, or a combination of these. The outer cover protects the reinforcement layers. A special rubber is used for the outer cover that resists abrasion and exposure to weather, oil, and dirt.

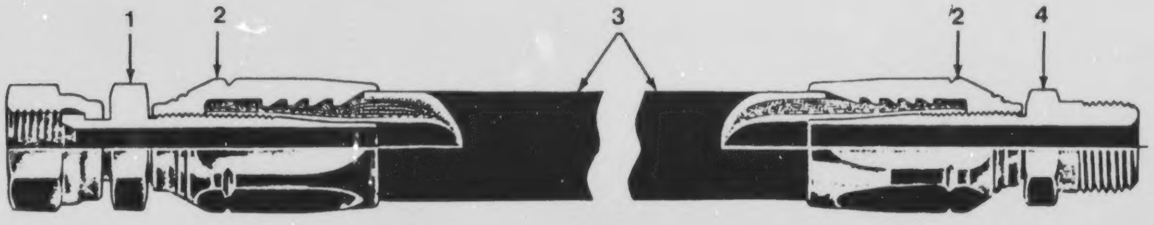


(1-165)
FLEXIBLE HOSE CONSTRUCTION

Courtesy of John Deere Ltd

Types Of Hose

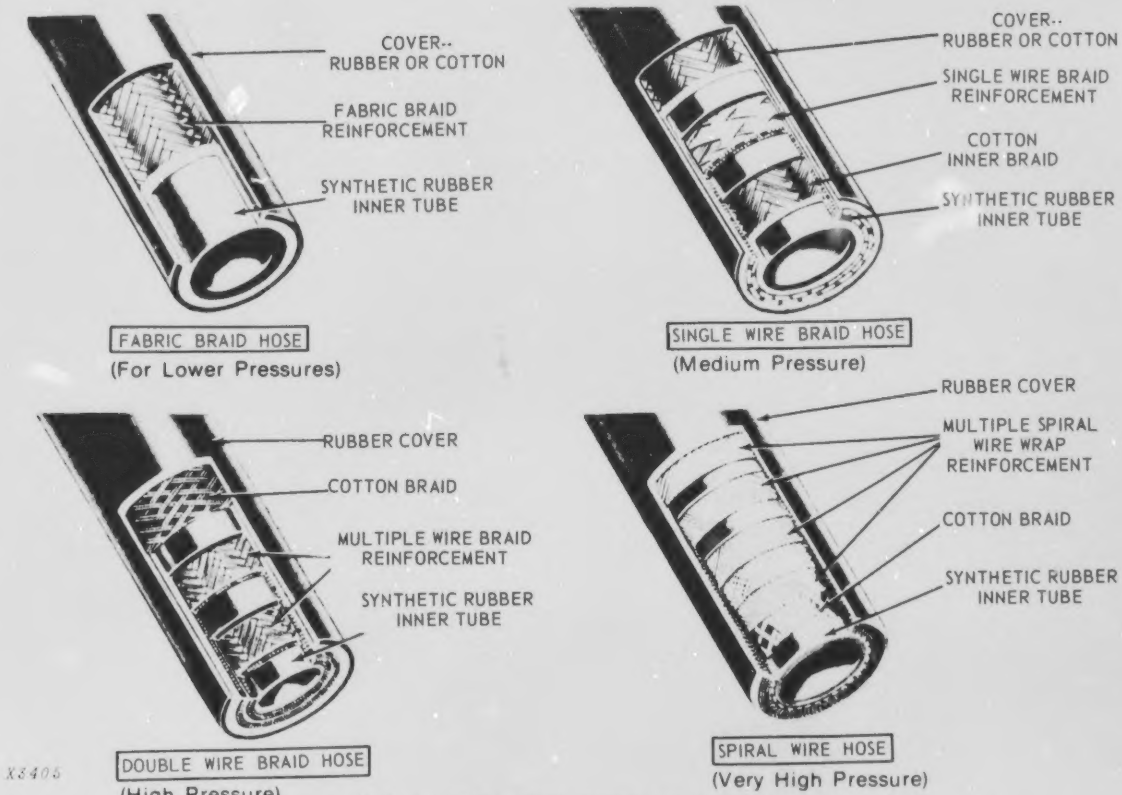
There are four common types of hoses, each differing in the strength of their wall construction (Figure 1-166). From a repairman's point of view, the important point to note about differnt types of hose is that each hose is constructed to withstand the conditions and pressures of a certain system. Therefore, when a hose is replaced, the new one must be exactly the same type and size as the one removed.



1—Nipple 2—Socket 3—Hose 4—Nipple

(1-164 CUTAWAY VIEW OF A TYPICAL FLEXIBLE HOSE AND REUSABLE FITTINGS

Courtesy of Terex, Division of General Motors Corporation


COVER-- RUBBER OR COTTON
FABRIC BRAID REINFORCEMENT
SYNTHETIC RUBBER INNER TUBE
COVER-- RUBBER OR COTTON
SINGLE WIRE BRAID REINFORCEMENT
COTTON INNER BRAID
SYNTHETIC RUBBER INNER TUBE
RUBBER COVER
COTTON BRAID
MULTIPLE WIRE BRAID REINFORCEMENT
SYNTHETIC RUBBER INNER TUBE
RUBBER COVER
MULTIPLE SPIRAL WIRE WRAP REINFORCEMENT
COTTON BRAID
SYNTHETIC RUBBER INNER TUBE
X3405

FABRIC BRAID HOSE
(For Lower Pressures)

SINGLE WIRE BRAID HOSE
(Medium Pressure)

DOUBLE WIRE BRAID HOSE
(High Pressure)

SPIRAL WIRE HOSE
(Very High Pressure)

(1-166) THE FOUR TYPES OF HOSES

Courtesy of John Deere Ltd.

1. **Fabric Braid Hose**

   (a) Reinforcement: Woven fiber reinforced with spiral wire to prevent collapse.
   Use: Lines for Petroleum-base hydraulic oils, gasoline or fuel oil. In suction lines or in low-pressure return lines.

   (b) Reinforcement: One-fiber braid.
   Use: Hydraulic oil return lines only, or general-purpose fuel oil, gasoline, water, anti-freeze mixtures, air and other chemicals.

   (c) Reinforcement: Two fiber braids.
   Use: Hydraulic oil return lines only, or general purpose fuel oil, gasoline, water, anti-freeze mixtures, air, and other chemicals.

Note: Fabric braid, low-pressure hose is not recommended for hydraulic pressure lines.

2. **Single Wire Braid Hose**

   Reinforcement: one braid or high tensile steel wire.

   Use: Hydraulic oil lines, fuel oil, gasoline or water lines.

3. **Double Wire Braid Hose**

   Reinforcement: Two or more braids of high tensile steel wire.

   Use: High pressure hydraulic oil lines, fuel oil, gasoline or water lines.

Note: Both single and double wire braid hose are widely used in the heavy duty mechanics field.

4. **Spiral Wire Hose**

   Reinforcement: Multiple spiral of high tensile steel wire and one fiber braid.

   Use: Very high pressure hydraulic oil lines or fuel oil lines.

Note: Spiral wire hose is recommended for systems having high surge peaks. Surges can cause weak spots in wire braid hose, but spiral wire reinforced hose does not weaken under high surges.

Selecting Hose

The following chart will help you to select the proper hose for any pressure application. Find the size of the hose you need and read across to the system working pressure nearest your application. If you find it in column 1, use a single wire braid hose; if in column 2, use a double wire braid hose; or in column 3, a spiral wire hose.

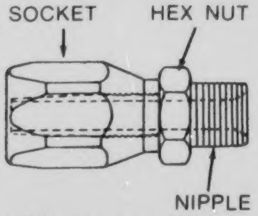
SELECTING HOSE FOR VARIOUS PRESSURES*

Hose Size in Inches	1. Use SINGLE WIRE BRAID Hose If System Working Pressure Equals . . .	2. Use DOUBLE WIRE BRAID Hose If System Working Pressure Equals . . .	3. Use SPIRAL WIRE Hose If System Working Pressure Equals . . .
¼"	3000 psi	5000 psi	- - -
⅜"	2250 psi	4000 psi	5000 psi
½"	2000 psi	3500 psi	4000 psi
⅝"	1750 psi	2750 psi	- - -
¾"	1500 psi	2250 psi	3000 psi
1"	800 psi	1875 psi	3000 psi
1¼"	600 psi	1625 psi	3000 psi
1½"	500 psi	1250 psi	3000 psi
2"	350 psi	1125 psi	2500 psi

*Note how larger hoses are recommended for lower pressures rather than smaller ones of the same construction.

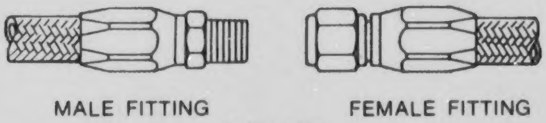
Hose Fittings

Fittings are couplers at the ends of hoses that connect the hose to a component or to another line. There are male and female fittings: male fittings have a socket and a nipple with a hex nut (Figure 1-167), while female fittings have a socket and a nipple with a swivel nut (Figure 1-168). Female fittings are sometimes called swivel ends. Hose fittings have several methods of sealing the threaded end (Figure 1-169).


SOCKET
HEX NUT
NIPPLE

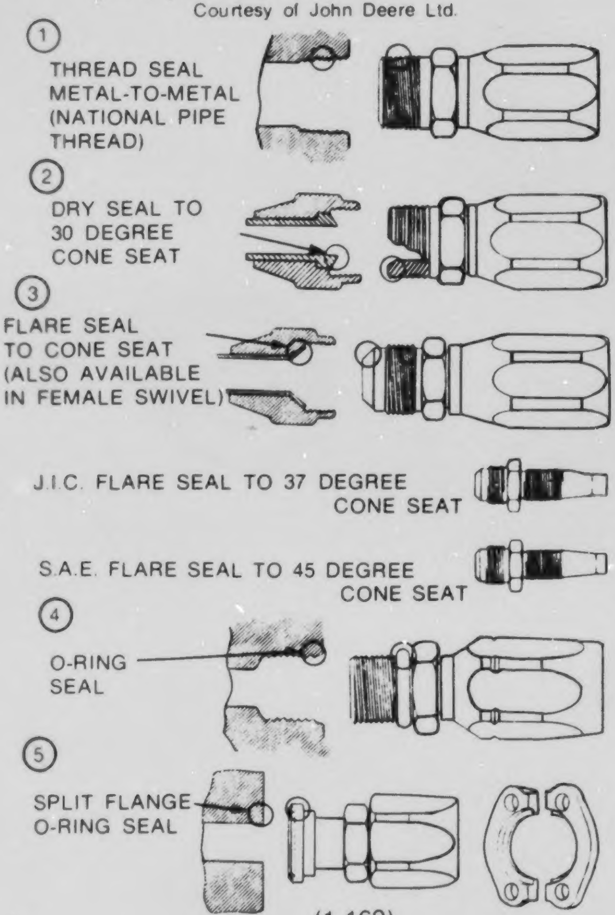
(1-167) MALE FITTING

Courtesy of John Deere Ltd.


MALE FITTING
FEMALE FITTING

(1-168)

Courtesy of John Deere Ltd.


①
THREAD SEAL
METAL-TO-METAL
(NATIONAL PIPE
THREAD)
②
DRY SEAL TO
30 DEGREE
CONE SEAT
③
FLARE SEAL
TO CONE SEAT
(ALSO AVAILABLE
IN FEMALE SWIVEL)
J.I.C. FLARE SEAL TO 37 DEGREE
CONE SEAT
S.A.E. FLARE SEAL TO 45 DEGREE
CONE SEAT
④
O-RING
SEAL
⑤
SPLIT FLANGE
O-RING SEAL

(1-169)

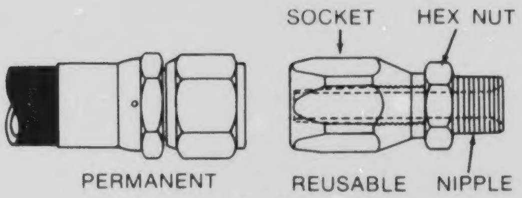
FIVE MAJOR WAYS OF SEALING HOSE FITTINGS

Courtesy of John Deere Ltd.

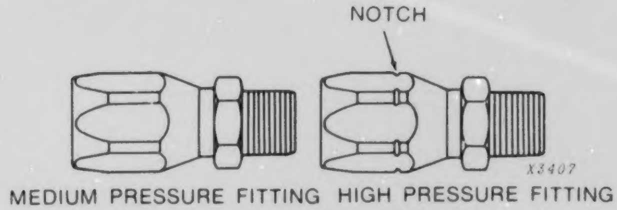
Some fittings (called permanent) are thrown away when the hose is replaced, where as others (reusable) are saved from damaged hose and attached to a new hose cut from stock. Permanent hose fittings are crimped or swedged onto the hose (Figure 1-170). Reusable fittings are either pushed, screwed, or clamped onto the hose. Make-up procedures for reusable fittings are illustrated in Figure 1-171.

There are low pressure, medium-pressure and high-pressure fittings. High-pressure fittings are usually marked with a notch, whereas medium and low pressure fittings have no notch (Figure 1-172). Never intermix a male and female coupler of different pressure rating.

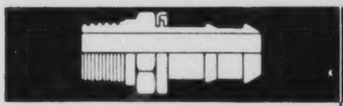
Besides identifying high pressure fittings, the notch markings also act as a gauge for the length of the outer cover that must be removed (skived) from the hose so that the socket will fit. Note, however, that hose is available called no-skive hose that does not require the outer layer be removed for the socket to fit. Be sure when using no-skive hose that you match it with the right size fitting.



(1-170)

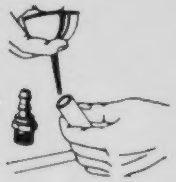


(1-172) HOSE FITTINGS

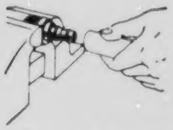


SOCKETLESS
(Low Pressure)

ASSEMBLY

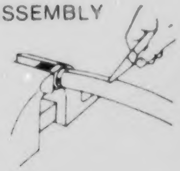


1. Cut hose to length with a sharp knife. Oil inside of hose and nipple liberally.

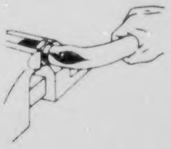


2. Push hose on fitting until it bottoms underneath protective cap.

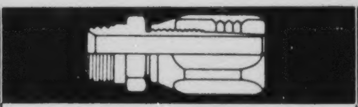
DISASSEMBLY



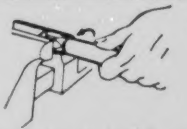
1. Slit hose from protective cap to end of nipple.



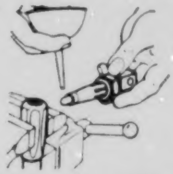
2. Bend hose and snap it off with a quick pull.



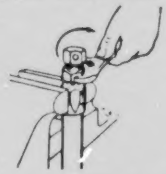
SOCKET AND NIPPLE
(Medium Pressure,
Single Wire Braid Hose)



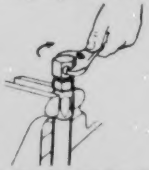
1. Cut hose to length with fine tooth hacksaw or cut-off wheel. Skive if required (see at right). Screw hose counterclockwise into socket until it bottoms. Back off ¼-turn.



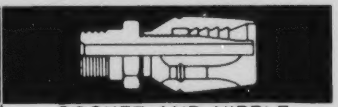
2. For male ends, if required: insert assembly tool mandrel (of correct size) into nipple and oil nipple threads, assembly tool, and inside of hose. If a mandrel is not available, a drill bit of the size that fits into the fitting works well. Insert the bit shank, first through the fitting, then into the hose. Doing this will prevent the inner liner of the hose from bunching up inside of the fitting and causing an unwanted check value.



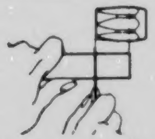
3. For male ends, screw nipple clockwise into socket until snug against socket.



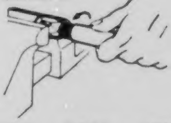
4. For female ends, tighten nipple and nut on assembly tool if required. Screw nipple clockwise into socket. Leave 1/32 in to 1/16 in clearance between nut and socket.



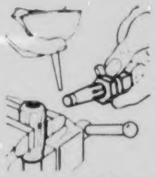
SOCKET AND NIPPLE
(High Pressure — Notch on Socket)
(Multiple Wire Braid Hose)



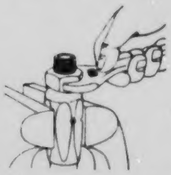
1. Cut hose to length. To strip off protective cover (if necessary) cut around hose down to metal wire reinforcement, then cut cover lengthwise and pull off cover. Clean wire with wire brush or soft wire wheel. Avoid flaring or fraying wire reinforcement.



2. Screw hose counterclockwise into socket until it bottoms.



3. Oil nipple threads and inside of hose liberally. Use grease for larger sizes.



4. Screw nipple clockwise into socket. Leave 1/32 in. to 1/16 in. clearance.

Courtesy of John Deere Ltd

(1-171)
INSTALLING REUSABLE HOSE FITTINGS

Installation of Hose

See Block 3, Hydraulics.

Good Practices When Installing Fittings

1. Be sure the working pressure rating of the fitting corresponds to that of the hose. Also, the make of the hose and fittings should be the same.
2. Be sure seal replacements match the fitting.
3. Use flared adapters or elbow hose fittings where possible instead of pipe adapters.
4. Improve the line routing by use of 45 degree and 90 degree adapters or elbows.
5. Attach male ends of hose assemblies before female ends so the hose does not twist.
6. Tighten swivel nuts only until snug. Do not overtighten them. Swivel nuts, unlike pipe threads, don't require compression of the threads to seal. As a rule, tighten the fitting until finger tight, then use wrenches to tighten the fitting two extra flats. If leakage occurs after operation, tighten one extra flat.
7. Tighten only the nipple hex nut and not the socket.
8. Use open-end wrenches for assembly: do not use pipe wrenches.
9. Use two wrenches where necessary to prevent twisting of hoses, one wrench to hold the hose and one to tighten the swivel nut.
10. Tighten the fitting on the hose, not the hose on the fitting.
11. Use pipe sealing compound on male threads only and make sure the compound is compatible with the hydraulic oil. Do not use sealing compound on swivel nuts.

Hose Adapters

See S.A.E. Flared Tube Fittings a few pages on.

Failure Of Hose Fittings

Leakage is the most common failure of hose fittings; it is usually the result of stripped threads, damaged O-rings, or mismatched seals. Failures can be caused by:

- — improperly assembling fittings in hose ends.
- — overtightening swivel nuts while leaving pipe threads loose
- — the fitting being hit during operation.
- — using too much sealing compound (pipe dope) which restricts the flow.
- — using a low-pressure socket in a high-pressure system.
- — mismatching fittings and hoses.

PIPES AND TUBES

Pipes and tubes are referred to as rigid lines (Figure 1-173). The choice between pipe or tubing depends on the system's pressure and flow. The advantages of tubing include easier bending and flaring, fewer fittings, nicer appearance, better capacity for reuse, and less leakage. However, pipe is cheaper and will carry larger volumes under higher pressures. Pipe is used where straight-line hookups cannot be avoided and where more permanent installations are needed.

Materials

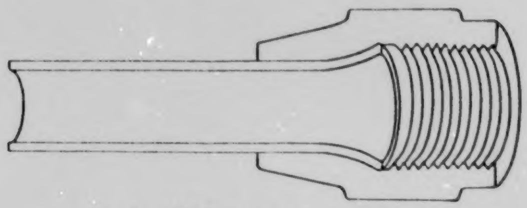
Pipes for hydraulic lines should be made of seamless cold-drawn mild steel. Galvanized pipe should not be used because the zinc coating may flake or scale and damage the hydraulic valves and pumps. Tubing can be made from a variety of materials:

Copper — limited to low pressure hydraulic systems with little vibration. Copper tends to become brittle when flared and subjected to high heat.

Aluminum — has good flaring and bending characteristics, but is limited to low pressure use.

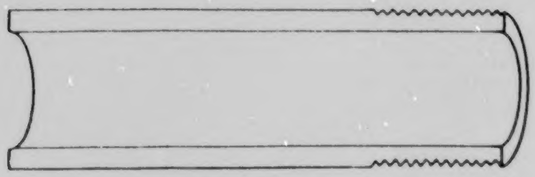
Plastic — used in low pressure hydraulic applications only.

Steel — has become the accepted standard in hydraulics where high pressures are encountered. There are two types of steel tubing: seamless and electric welded.



(1-173) TUBING

Courtesy of John Deere Ltd.



(1-173) PIPE

Courtesy of John Deere Ltd.

Strength and Line Size

Strength and line size are two other important characteristics of pipes and tubes. Wall thickness determines the strength of the line; the thicker the wall, the stronger the line. The inner diameter of the line determines its size. Note the importance of line size: too small a line would cause pressure drops, restrict flow, and create heat (i.e., power loss). A line too large is cumbersome and costly.

The sizes of tubes are given as fractions of an inch or as dash numbers representing sixteenths of an inch. These sizes give the nominal dimensions of the tube's outside diameter.

Pipe sizes are given by the nominal dimensions of their inside diameters, and by a wall thickness rating. Wall thickness ratings are represented by schedules:

Schedules 40: standard pipe
80: extra heavy pipe
160: double extra heavy

Failures

If pipes and tubes are of good quality and are well maintained, failures should rarely occur. Maintenance on pipes and tubes includes checking for:

- — loose clamps that cause vibrations.
- — lines that may have been accidentally hit, bent, or pinched during operation.
- — wet spots that could mean a pin-hole leak in the line.

Pipe Fittings

Pipe is normally connected by taper threading its outside diameter with a die and then screwing it into a taped hole. Sealing compound is applied when the pipe and taped hole do not have dryseal or precision cut threads.

Besides sealing compounds, pipe threads and connections can also be sealed by using fittings with pipe lock nuts. These fittings have a free nut with a Teflon seal ring. When positioned and tightened, the nut forms the seal and lock the fitting in position. Pipe fittings are available in many differnt styles, both male and female. They are constructed of three types of material:

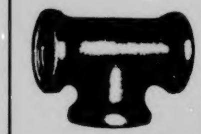
1. Brass in small sizes for low and medium pressures.
2. Cast iron in large sizes for low and medium pressures (Figure 1-174).
3. Steel in varying sizes for high pressure hydraulic applications. Note that for high pressures, i.e., pressures above 1000 psi, fittings must be welded.

IRON PIPE THREAD FITTINGS

Made with tapered pipe threads and machined to fit perfectly in conformity with the modified standards of the Society of Automotive Engineers. Only the finest brass castings and rods are used.

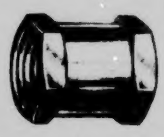
B-100 Elbow

Pipe Thread
1/8
1/4
3/8
1/2



B-101 Tee

Pipe Thread
1/8
1/4
3/8
1/2

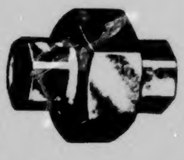


B-103 Coupling

Pipe Thread
1/8
1/4
3/8
1/2

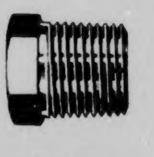
B-113 Long Nipple

Pipe Thread	Length
1/8	1-1/2
1/4	1-1/2
3/8	1-1/2
1/2	1-1/2
1/8	2
1/4	2
3/8	2
1/2	2
1/8	2-1/2
1/4	2-1/2
3/8	2-1/2
1/2	2-1/2
1/8	3
1/4	3
3/8	3
1/2	3
1/8	3-1/2
1/4	3-1/2
3/8	3-1/2
1/2	3-1/2



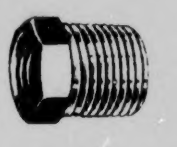
B-104 Union

Pipe Thread
1/8
1/4
3/8
1/2



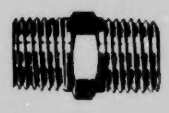
B-109 Plug

Pipe Thread
1/8
1/4
3/8
1/2



B-110 Bushing

Pipe Thread
1/4x1/8
3/8x1/4
3/8x1/8
1/2x3/8
1/2x1/4
3/4x3/8
3/4x1/2

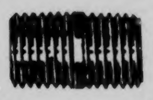


B-122 Hex Nipple

Pipe Thread
1/8x1/8
1/4x1/4
3/8x3/8

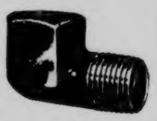
B-124 45° Elbow

Pipe Thread
1/8
1/4



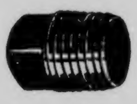
B-112 Close Nipple

Pipe Thread
1/8
1/4
3/8
1/2



B-116 Street Elbow

Pipe Thread
1/8
1/4
3/8
1/2



B-121 Square Head Plug

Pipe Thread
1/8
1/4
3/8
1/2

(1-174)

Courtesy of E. Edelman and Co.

Good Practices For Installing Pipes and Pipe Couplers

Installing Pipes

1. Always replace pipes with ones of identical size, shape and material. Do not make substitutions.
2. Where possible, avoid straight-line hookups, especially for short distances, because they do not allow for enough expansion or contraction during heat and pressure changes.
3. When installing long pipe lines, use brackets and clamps to reduce strain and fatigue on the pipe. Pipe-fitted components or heavy fittings should also be bolted down to eliminate stress on the pipe.
4. Use bulkhead fittings where lines pass through a wall or beam. They not only provide ease of dismantling, but also give added support.
5. Replacement pipe must be clean and free from rust and scale.

Installing Pipe Fittings

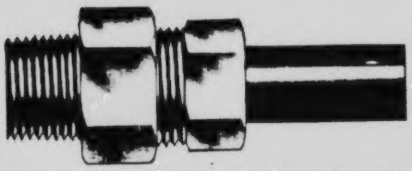
1. When cutting pipe threads, use sharp standard pipe taps or dies, and a good cutting oil. These threads will keep leakage to a minimum.
2. Remove burrs from both the inside (with a reamer) and outside of the pipe end.
3. Clean all foreign matter from pipes and fittings.
4. Use union connectors at various points to aid later removals.
5. When using pipe sealing compound, cover only two-thirds of the threaded male end. Never apply pipe compound to female threads. Make certain the pipe compound is compatible with the hydraulic fluid. Never use shellac as a sealer.

Tube Fittings

Fittings connect tubes to components; they must form a seal without the tube having to turn. Tubing, unlike pipe, is too thin to be threaded, so another method must be used to attach the tube to the fitting. Although there are many types of tube fittings available, they can be classified into two basic groups: flared fittings and compression fittings.

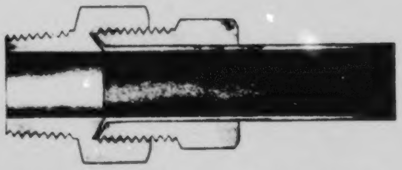
Flared fittings: are used with the thin-walled tubing that is easily flared. Sealing is by metal-to-metal contact. The flared end of the tube is squeezed between the mating surfaces as the fitting is firmly tightened to another connection. There are two common types of flared fittings used in the mechanical trade: inverted flare tube fittings and SAE flare tube fittings.

Inverted flared tube fittings: are illustrated in Figure 1-175. Note especially the male elbow and straight male connector. In making a connection the nut is first placed over the tubing with countersunk ends towards the tubing end. The tubing is then flared, and the nut when tightened against the flare provides a seal. Note in Figure 1-175 that when identifying an inverted flared fitting, the tube size is given first, then the pipe thread size of the fitting.

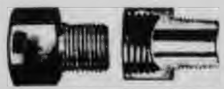
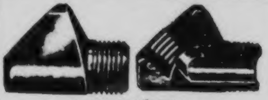


ASSEMBLY OF B-24 CONNECTOR
COMPLETE WITH B-21 NUT

INVERTED FLARED TUBE FITTINGS



CUT-AWAY OF B-24 CONNECTOR
COMPLETE WITH B-21 NUT

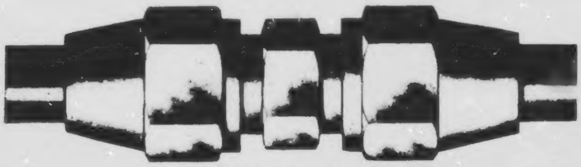
 B-21 Nut	 **B-22 Male Elbow**		 **B-23 Union**	 **B-24 Male Connector**		 **B-25 45° Elbow**	
Tube Size	**Tube Size**	**Pipe Thread**	**Tube Size**	**Tube Size**	**Pipe Thread**	**Tube Size**	**Pipe Thread**
3/16	3/16	1/8	3/16	3/16	1/8	3/16	1/8
1/4	1/4	1/8	1/4	1/4	1/8	1/4	1/8
5/16	1/4	1/4	5/16	1/4	1/4	5/16	1/8
3/8	5/16	1/8	3/8	5/16	1/8	3/8	1/4
1/2	5/16	1/4		5/16	1/4		
	3/8	1/4		3/8	1/4		
	1/2	3/8					

(1-175)

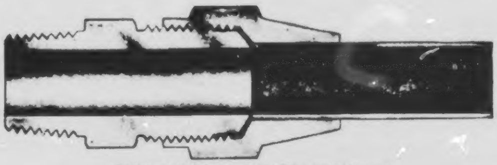
Courtesy of E Edelman and Co

SAE tube fittings (Figure 1-176): are the most common fittings found on heavy duty equipment. They are used not only to connect tubing but also as adapters for replaceable hose fittings. For example, the B48 male connector is the adapter fitting used with a female swivel fitting on a hose end. Figure 1-177 illustrates places where adapters (i.e., SAE flared tube fittings) are used. When ordering SAE flared tube fittings, as with inverted fittings, the tube size is given first, then the pipe size.

SAE flared tube fittings are manufactured to the exact specifications of the Society of Automotive Engineers. In making a connection with these fittings, first place the nut over the tubing end with the large threaded hole towards the tube end, then flare the end of the tubing. The fitting has a tapered seat and the tubing is held between the tapered inside of the nut and the beveled face of the fitting. This makes a very tight seal and secure joint that will withstand great pressure.

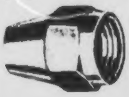
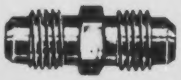
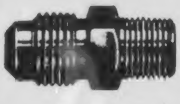
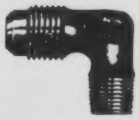


ASSEMBLY OF B-42 UNION WITH B-41 NUTS



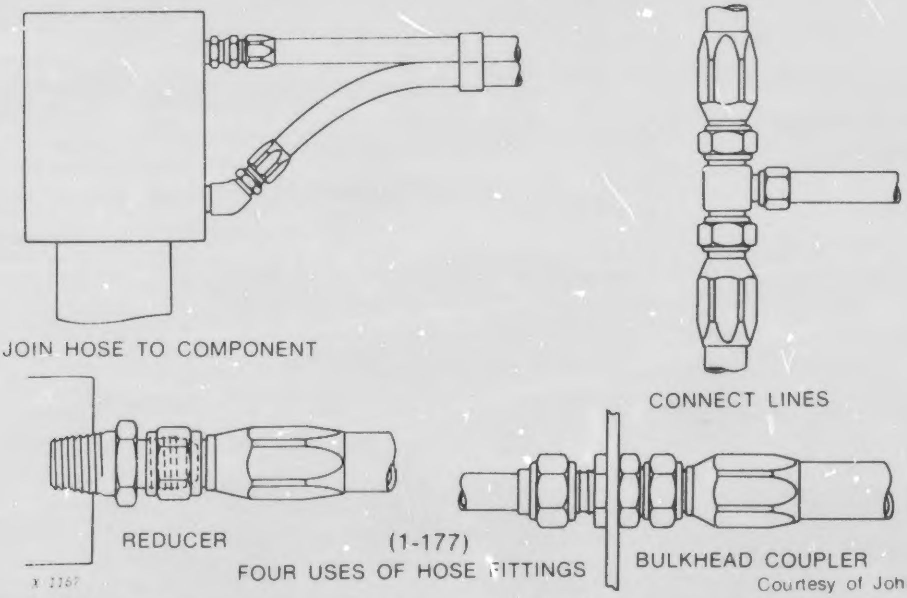
CUT-AWAY ASSEMBLY OF B-48 CONNECTOR WITH B-41 NUT

S.A.E. FLARED TUBE FITTINGS

 B-41 Nut	 **B-41S Short Nut**	 **B-42 Union**	 **B-44 Tee**	 **B-48 Male Connector**		 **B-49 Male Elbow**	
Tube Size	Tube Size	Tube Size	Tube Size	Tube Size	Pipe Thread	Tube Size	Pipe Thread
3/16	3/16	3/16	3/16	3/16	1/8	3/16	1/8
1/4	1/4	1/4	1/4	1/4	1/8	1/4	1/8
5/16	5/16	5/16	5/16	1/4	1/4	1/4	1/4
3/8	3/8	3/8	3/8	5/16	1/8	5/16	1/8
1/2	1/2	1/2	1/2	5/16	1/4	5/16	1/4
5/8	5/8	5/8	5/8	3/8	1/4	3/8	1/4
3/4	3/4	3/4	3/4	3/8	1/8	3/8	1/8
				3/8	3/8	3/8	3/8
				1/2	3/8	1/2	3/8
				1/2	1/2	1/2	1/2
				5/8	1/2	5/8	1/2
				3/4	1/2	3/4	1/2

(1-176)

Courtesy of E Edelman and Co

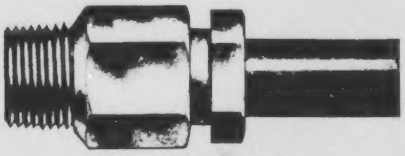


(1-177)
FOUR USES OF HOSE FITTINGS

Courtesy of John Deere Ltd

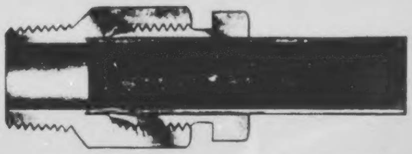
Compression fittings: the advantage of compression fittings is that a flaring tool is not needed to install them. There are two common types of compression fittings used in the mechanical trades: double compression fittings and solderless compression fittings.

Double compression fittings (Figure 1-178): consist of a nut with an integral sleeve and a body internally threaded with a machined seat. To assemble these fittings insert the copper tubing through the nut into the body of the fitting as far as the shoulder of the body permits. Tighten the nut to the body and the assembly is complete. The sleeve end of the nut is wedged by the tapered seat of the body and bites into the copper tubing to form a liquid tight seal. Since it is crimped to the tube, the fitting also provides a swivel for removing the tube.



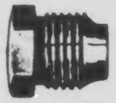
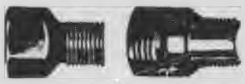
B-12 CONNECTOR COMPLETE WITH B-11 NUT

DOUBLE COMPRESSION FITTINGS



CUT-AWAY OF B-12 CONNECTOR WITH B-11 NUT ASSEMBLY

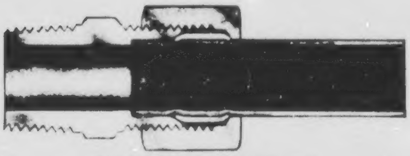
DOUBLE COMPRESSION FITTINGS

 **B-11 Nut**	 **B-12 Male Connector**		**B-15 Male Elbow**	
Tube Size	Tube Size	Pipe Thread	Tube Size	Pipe Thread
1/8	1/8	1/8	1/8	1/8
3/16	3/16	1/8	3/16	1/8
1/4	3/16	1/4	1/4	1/8
5/16	1/4	1/8	5/16	1/8
3/8	5/16	1/8	3/8	1/4
1/2	3/8	1/4	1/2	3/8
	1/2	3/8		

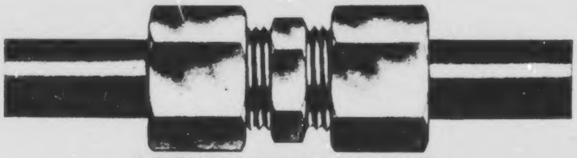
(1-178) Courtesy of E. Edelman and Co.

Common solderless compression fittings: are shown in Figure 1-179. They are used on low pressure circuits such as gasoline supply lines. They should not be used on brake lines.

Solderless compression fittings consist of a nut, a double tapered sleeve, and a body. To make a connection, place the nut and sleeve over the tubing and insert the tube into the body of the fitting as far as possible. The wedging action of the sleeve between the body and the nut makes a tight joint.

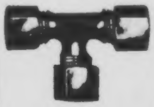


CUT-AWAY VIEW OF
B-68 CONNECTOR



ASSEMBLY OF B-62 FITTING

SOLDERLESS COMPRESSION FITTINGS

B-60 Sleeve	**B-61 Nut**	**B-62 Union**	 **B-64 Tee**	**B-65 Elbow**
Tube Size	Tube Size	Tube Size	Tube Size	Tube Size
1/8	1/8	1/8	1/8	1/8
3/16	3/16	3/16	3/16	3/16
1/4	1/4	1/4	1/4	1/4
5/16	5/16	5/16	5/16	5/16
3/8	3/8	3/8	3/8	3/8
7/16	7/16	1/2	1/2	1/2
1/2	1/2	5/8	5/8	5/8
5/8	5/8	3/4	3/4	3/4
3/4	3/4			

B-68 Male Connector		**B-69 Male Elbow**	
Tube Size	Pipe Thread	Tube Size	Pipe Thread
1/8	1/8	1/8	1/8
3/16	1/8	3/16	1/8
1/4	1/8	1/4	1/8
1/4	1/4	1/4	1/4
5/16	1/8	5/16	1/8
5/16	1/4	5/16	1/4
3/8	1/4	3/8	1/4
3/8	1/8	3/8	1/8
3/8	3/8	3/8	3/8
7/16	1/4	1/2	3/8
1/2	3/8	1/2	1/2
1/2	1/2	5/8	1/2
5/8	1/2	3/4	1/2
3/4	1/2		

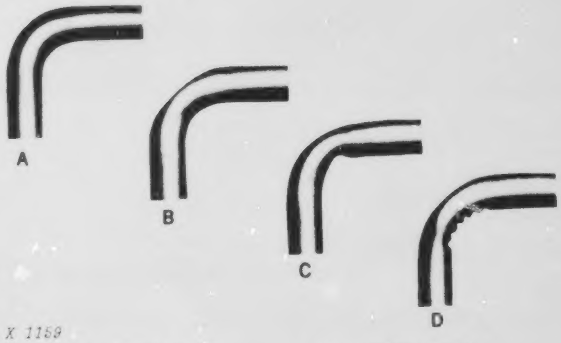
(1-179)

Courtesy of E. Edelman and Co

Good Practices When Installing Tubes and Tube Fittings

Installing Tubes

1. Always replace tubes with ones of identical shape, size and material.
2. Use as few fittings as possible by making bends in the tubing where practical.
3. Route the tubing as follows:
   - (a) Use as few sharp bends as you can, and make the bends as gradual as possible. Use the proper tube bending tools to prevent flattened, kinked, or wrinkled bends (Figure 1-180). The bends should be accurate and smooth so that they do not restrict flow. As a general rule, the radius of the bend should be three to five times the diameter of the tubing, but follow the manufacturer's recommendations.
   - (b) Avoid routes that interfere with the operator, moving parts, access doors or controls. Keep the lines from protruding if possible.
   - (c) Avoid straight-line hookups where possible (Figure 1-181). They make the line difficult to remove and do not allow for enough expansion and contraction.
   - (d) Support long tubing runs with brackets or clamps. Group lines and clamp them together for a neater appearance.
   - (e) Do not route tubes through bulkheads or walls if you can avoid it. However, if it can't be avoided, use bulkhead connectors.



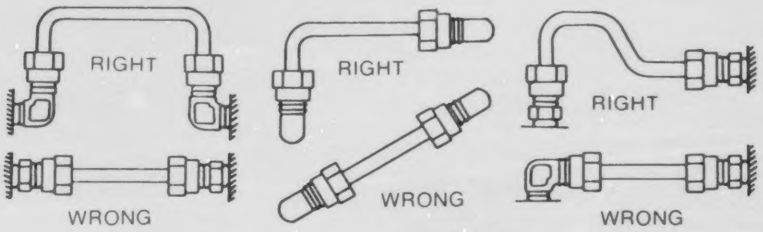
A–Good Bend
B–Flattened Bend
C–Kinked Bend
D–Wrinkled Bend

(1-180) GOOD AND BAD BENDS IN TUBING

Courtesy of John Deere Ltd.

Installing Tube Fittings

1. The most important rule for tightening tube fittings is: tighten only until snug. Do not over tighten. More damage has been done to tube fittings by over tightening than by any other cause.
2. Where necessary, use two wrenches on the fittings to avoid twisting the lines.
3. If a fitting starts to leak and appears loose, retighten it only until the leak stops.



(1-181) ROUTING OF TUBES

Courtesy of John Deere Ltd.

QUESTIONS — HOSES, PIPES, TUBES, FITTINGS AND ADAPTERS

1. The dash number used for sizing hydraulic hose refers to its inner diameter in:
   (a) 1/8th of an inch
   (b) 1/32nd of an inch
   (c) 3/16ths of an inch
   (d) 1/16th of an inch

2. Generally speaking as the size of a hose increases its working pressure:
   (a) decreases
   (b) increases
   (c) stays the same
   (d) none of the above

3. When making up a hose that requires the end to be skived to install the replaceable fitting, the amount skived is:
   (a) two times the diameter of the fitting
   (b) 1/2 the diameter of the hose
   (c) the length up to the notch on the fitting socket
   (d) the length of the fitting

4. Flexible hydraulic lines must be long enough to allow for:
   (a) vibration
   (b) heat expansion
   (c) full extension or action of the actuator
   (d) all of the above

5. JIC and SAE are the two types of reusable hose end fittings used in hydraulic system piping. These fittings:
   (a) are completely interchangeable
   (b) have different seating angles and thread pitches
   (c) have the same seating angles and different thread pitches

6. Why is galvanized pipe not recommended for hydraulic lines?

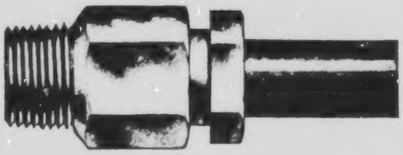
7. Why is copper tubing not recommended for hydraulic system piping?

8. Tubing is sized by its:
   (a) ID alone
   (b) OD alone
   (c) ID and wall thickness
   (d) OD and wall thickness

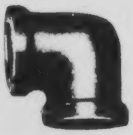
9. Piping is sized by its:
   (a) OD
   (b) ID
   (c) ID and wall thickness
   (d) OD and wall thickness

10. Match the following illustrations of fittings with their name:

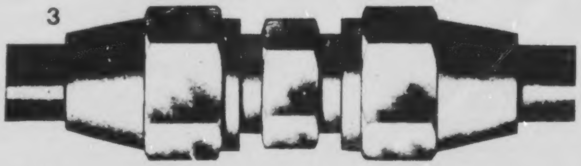
1



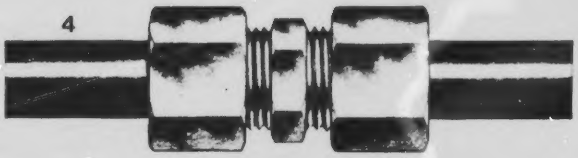
2



3



4



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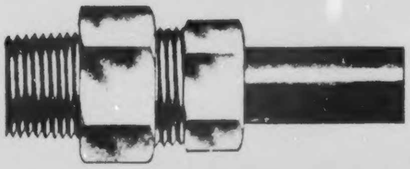


iron pipe fitting ________

solderless compression fitting ________

inverted flared fitting ________

double compression fitting ________

SAE flared fitting ________

LIFTING AND BLOCKING

Lifting and blocking equipment and lifting and lowering heavy components is a routine part of a mechanic's work. This section discusses common types of lifting equipment, chains, strings, rigging hardware, and stands and blocking found in heavy duty shops. Safety when lifting is stressed.

TYPES OF LIFTING EQUIPMENT

Cranes — Mobile
— Shop (overhead bridge, and portable gantry A-frame)

Forklifts

Hydraulic Hoists and Jacks

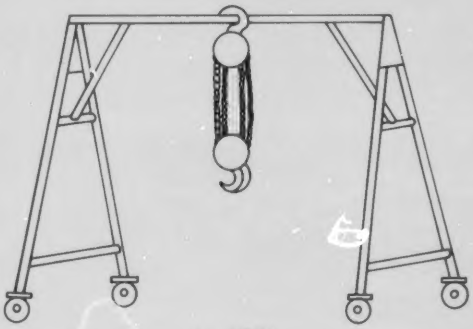
Mobile Cranes

There are many makes and sizes of mobile cranes with lifting capacities ranging from one or two tons to over a hundred tons. Mobile cranes can be diesel or gasoline powered, can have cable or hydraulic lift, and can have two, four, or six wheel drive depending on their size. A large hydraulic mobile crane is shown in Figure 1-182; the advantage of a crane like this is it can be moved quickly from job to job.

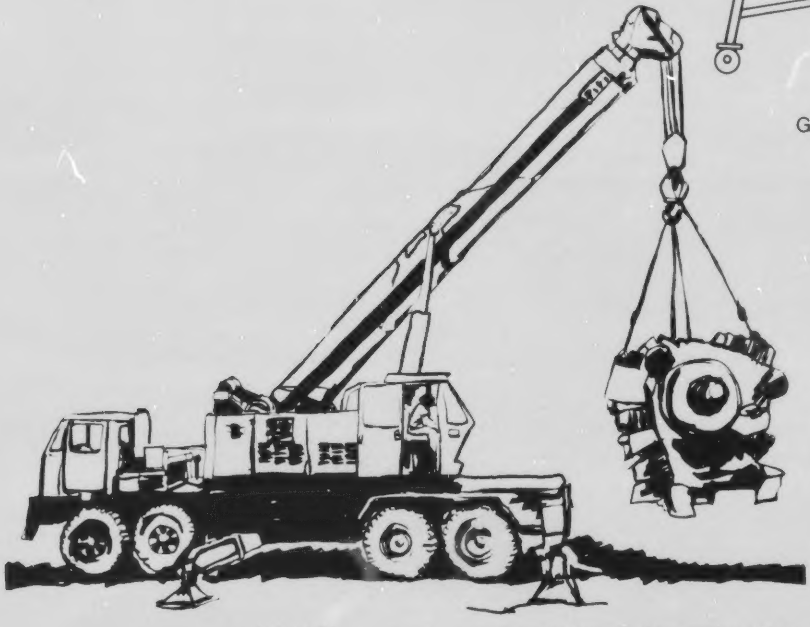
Shop Cranes

Some shops have overhead cranes that run on tracks. These tracks may be over top of a section of the shop or they may run the complete length of the shop. The crane hoist may be electric, air or hand operated, depending on its size and lifting capacity which can range from one or two tons to over fifty tons.

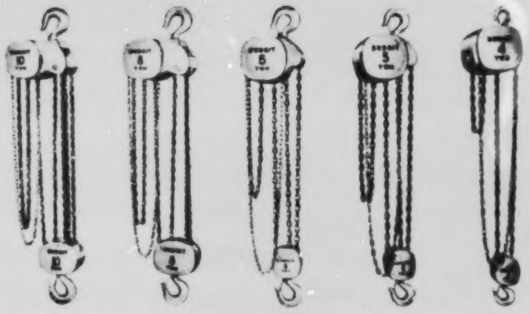
Gantry A-frame cranes (Figure 1-183) are common in smaller shops. They are equipped with large castor wheels permitting them to be moved around the shop to where ever they are needed. They have either heavy wall pipe or I-beam construction. Hoists used with A-frames (Figure 1-184) are usually hand operated, although smaller ones may use a lever-operated come along (Figure 1-185). Lifting capacities of gantry A-frames depend on the strength of the frames material and on the capacity of the hoisting equipment. Note that all overhead lifting equipment must have its lifting capacity clearly marked on it.



(1-183)
GANTRY A-FRAME CRANE



(1-182) Courtesy of Harnischfeger Corporation, P&H



(1-184) HAND HOISTS

Courtesy of Clark Equipment Co.

(1-185) COME ALONGS

Courtesy of Clark Equipment Co.

Fork Lifts

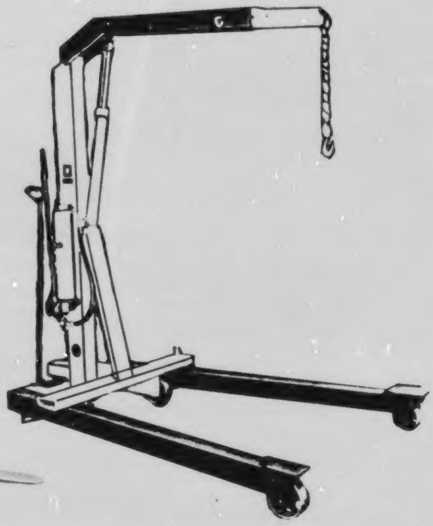
Forklifts (Figure 1-186) have become common pieces of lift equipment around mechanical shops mainly because of their mobility and versatility. Originally intended for moving loads on pallets from one spot to another, forklifts can also do various hoisting jobs in a shop. They are, however, limited in reach and height. Forklifts are available in lifting capacity from 2 to 20 tons and more.

HYDRAULIC HOISTS AND JACKS

Hydraulic hoists lift from above, while hydraulic jacks push from below. Both have single acting hydraulic cylinders, and have pumps and reservoirs integral to their assemblies. A typical mobile floor hoist is shown in Figure 1-187. The lifting reach can be changed by extending the boom in or out. However, keep in mind that as the boom extends, the lifting capacity decreases. Note that the lifting capacities of these types of mobile hoists are rated with the lift arm fully retracted.

(1-186)

Courtesy of Clark Equipment Co.

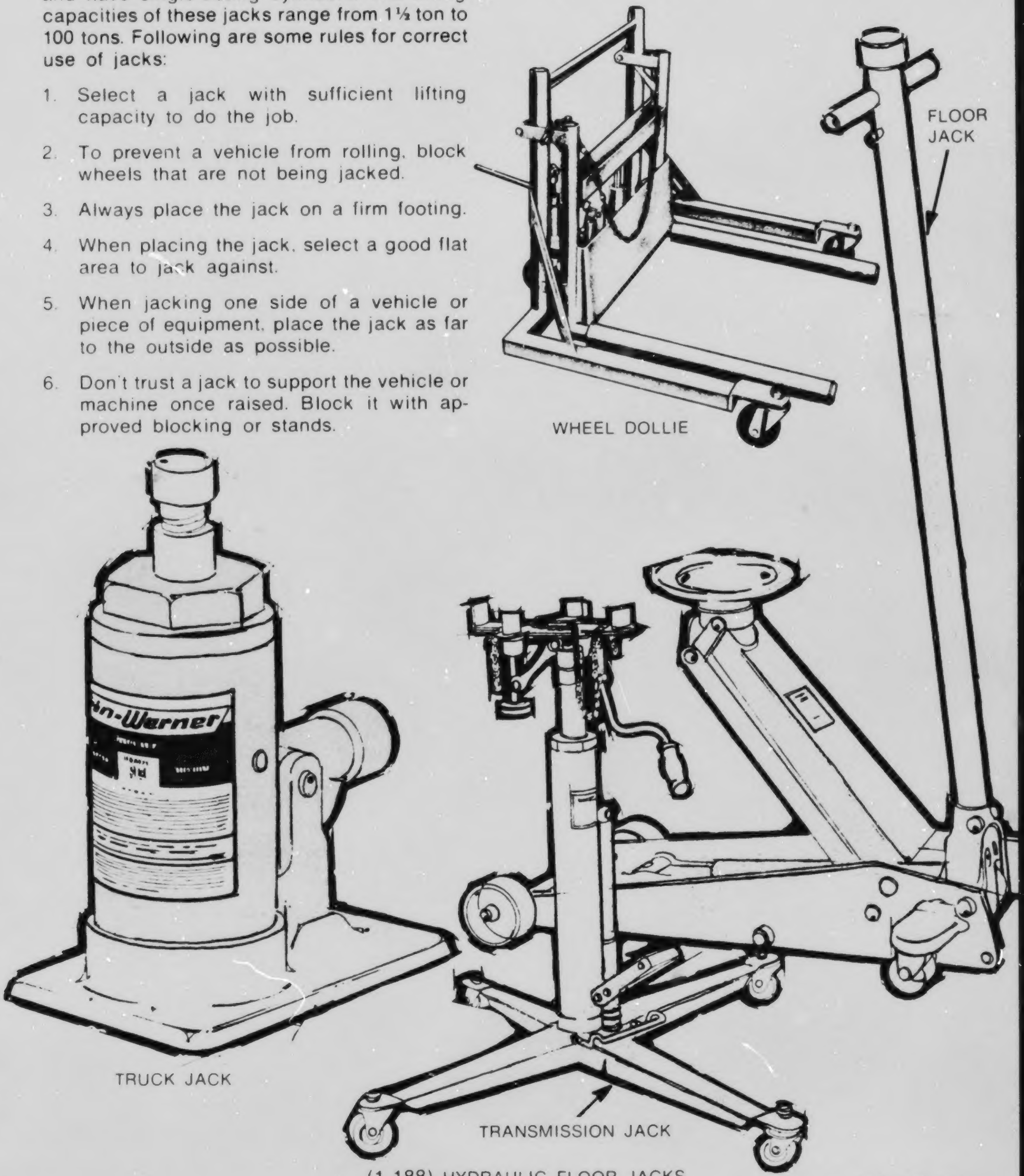


(1-187) HYDRAULIC FLOOR HOIST

Courtesy of Owatonna Tool Company

The hydraulic jacks used in heavy duty shops are: floor jacks, transmission jacks, and wheel dollies (Figure 1-188). These are all portable and have single-acting cylinders. The lifting capacities of these jacks range from 1½ ton to 100 tons. Following are some rules for correct use of jacks:

1. Select a jack with sufficient lifting capacity to do the job.
2. To prevent a vehicle from rolling, block wheels that are not being jacked.
3. Always place the jack on a firm footing.
4. When placing the jack, select a good flat area to jack against.
5. When jacking one side of a vehicle or piece of equipment, place the jack as far to the outside as possible.
6. Don't trust a jack to support the vehicle or machine once raised. Block it with approved blocking or stands.



(1-188) HYDRAULIC FLOOR JACKS

Courtesy of Hein-Werner

CHAINS AND SLINGS

To lift a load from above, regardless of the types of lifting equipment used, requires chains or slings. Chains and slings are often used interchangeably, whatever is available at the time.

CHAINS

A general rule of rigging is don't use chain if you can use wire rope. The reason for this is simple: if one link on a chain breaks, the whole chain breaks, whereas all the hundred or so wires on a wire rope must break before it will break. However, there are some jobs such as lifting engines, suspension parts and large, heavy castings where chain is better than wire rope. The chain is flexible, it doesn't kink like wire rope, it holds the piece well, and stands up to rough treatment. Note that all chain safe for lifting has an "A" stamped on its links standing for heat-treated alloy steel.

Chain is available in link thicknesses starting from 1/4 inch and increasing in increments of 1/8 inch. The lifting capacity of chain is rated according to link thickness, e.g., 3/8th inch chain has a capacity of 6600 pounds and 1/2 inch chain 11250 pounds.

Inspecting Chains

Inspect regularly used chains at least once a month. Each link of the chain must be checked. Chain inspecting procedures are:

1. Wash the chain in solvent.
2. Place the chain on a flat surface or suspend it.
3. Check for elongated or stretched links. Two signs of this are links that stick together, or a chain that won't hang straight. Stretched links are caused by overloading.
4. Check for worn, twisted, bent links. Also look for large nicks, cuts, gouges that could make the chain unsafe. Tables are available that show the allowable amount of wear or depth of cuts for chains.
5. Closely check for cracks in the links. If cracks are found, the chain is unsafe to use, and should be discarded.

Care and Use Of Chains

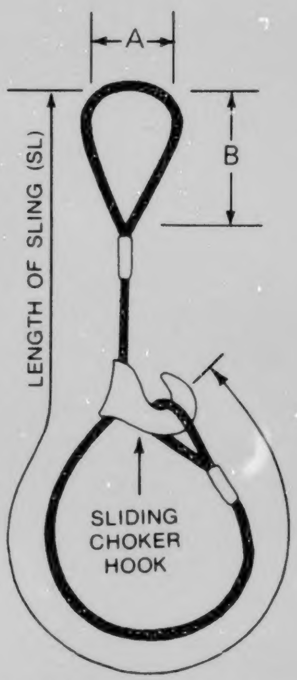
1. Don't overload chains. Know the lifting capacity of the chain, and know the weight of the object you're lifting.
2. Don't put a knot in a chain to shorten it, nor try to shorten it with a bolt.
3. Never replace links in a chain with shop-made ones.
4. Never weld or heat alloy steel chain links.
5. Don't try to lift a load with the tip of a chain hook.
6. Be sure that chain fittings are the correct size, type and grade for the chain.

WIRE ROPE SLINGS

Wire rope slings are used for straight lifting from lifting eyes, and for lifting objects of a shape that allows the rope to have gradual, uniform curvature when wrapped around it. Wire rope slings should not be placed around sharp corners because they will kink and thereby loose much of their lifting capacity.

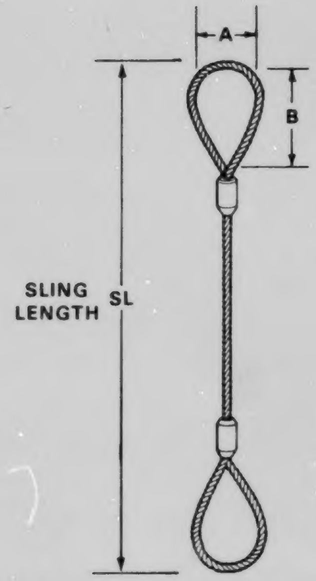
Wire rope slings are available in a number of diameter sizes, lengths and ends. Diameter sizes vary from one-quarter inch to two inches (See Figure 1-189). Lengths vary with the sling application, but there is a minimum length. Ends of slings are usually eye splices, the best being a mechanically crimped Flemish eye splice. Thimbles are recommended in the eyes (Figure 1-190).

Common configurations of wire rope slings are single (Figure 1-189), choker (Figure 1-191) and bridle (two, three and four part) (Figure 1-192).



(1-191) CHOKER SLING

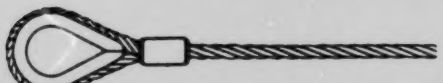
Courtesy of Martin-Black Wire Ropes Ltd.



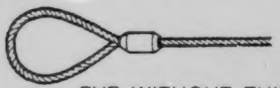
Rope Diameter Inches	Standard Loop Sizes Inches		Minimum Sling Length
	A	B	
¼	2	4	1′6″
5/16	2½	5	2′
⅜	3	6	2′
7/16	3	6	2′6″
½	4	8	2′6″
9/16	4	8	3′
⅝	5	10	3′
¾	6	12	3′6″
⅞	7	14	4′
1	8	16	4′6″
1⅛	9	18	5′
1¼	10	20	5′6″
1⅜	11	22	6′
1½	12	24	7′
1⅝	13	26	8′
1¾	14	28	8′
1⅞	15	30	9′
2	16	32	9′

(1-189) BASIC SLING SIZES

Courtesy of Martin-Black Wire Ropes Ltd.



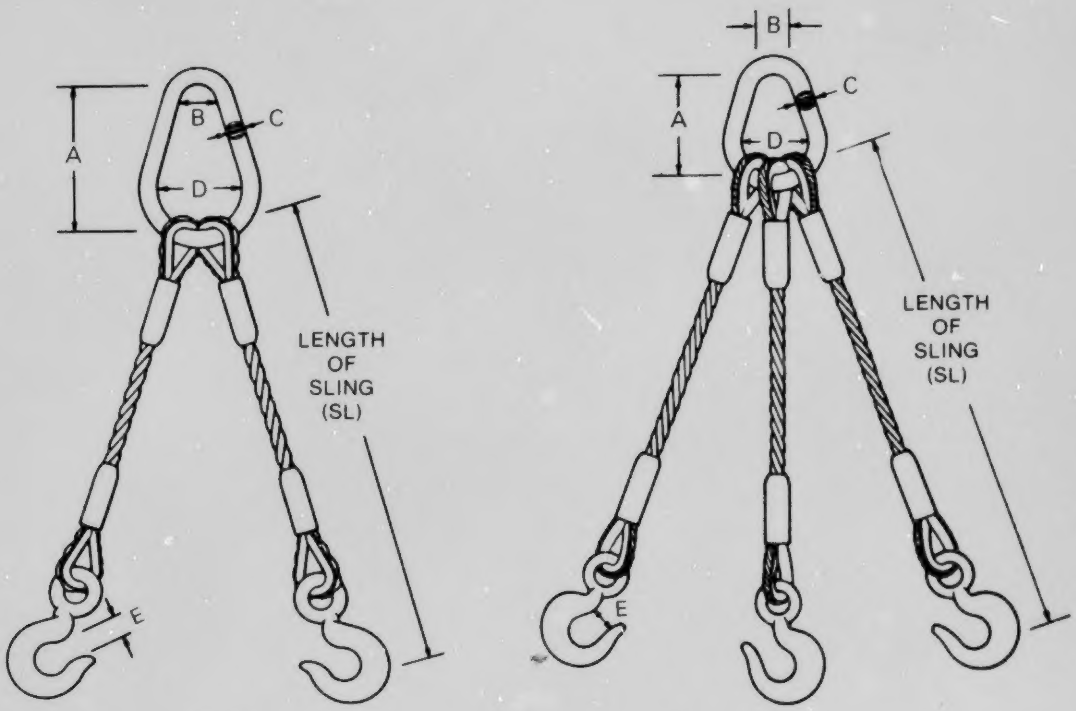
EYE WITH THIMBLE



EYE WITHOUT THIMBLE

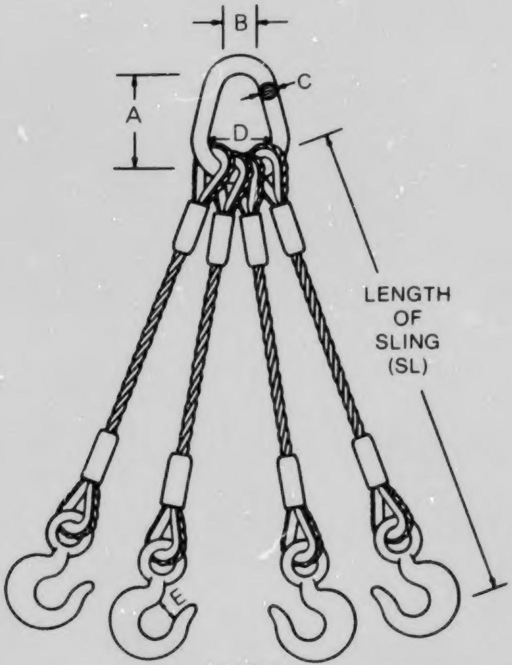
(1-190)

Courtesy of Martin-Black Wire Ropes Ltd.


B
C
A
D
E
LENGTH OF SLING (SL)
B
C
A
D
E
LENGTH OF SLING (SL)

2-PART

3-PART

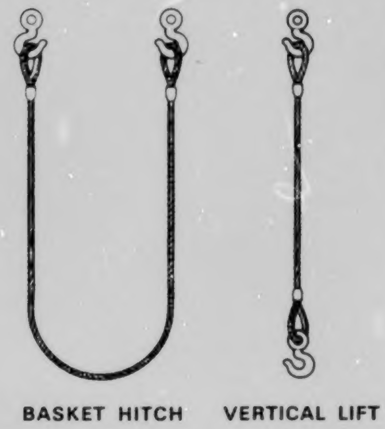

B
C
A
D
E
LENGTH OF SLING (SL)

4-PART

(1-192) BRIDLE SLINGS

Courtesy of Martin-Black Wire Ropes Ltd.

Lifting capacity is an important consideration with slings; it depends on wire rope diameter, sling configurations and lifting angle. Figure 1-193 shows the lifting capacities of single slings making both a vertical lift and a basket hitch lift. Note the greater lifting capacity of the two part basket hitch. The lifting capacity of bridle slings depends on the lifting angle of the line parts. For example, on a half inch, three part bridle sling, if the lifting angles are 30 degrees from the vertical, the sling's lifting capacity is 9730 pounds, but if the angles are increased to 60 degrees the lifting capacity is reduced to 5600 pounds. In other words, the greater the lifting angle of the line parts of a bridle sling the less its lifting capacity.



	BASKET HITCH	VERTICAL LIFT
Rope Diameter Inches	Pounds	Pounds
¼	1,840	920
⅜	4,040	2,020
½	7,470	3,740
⅝	11,210	5,600
¾	16,160	8,080
⅞	21,790	10,900
1	28,360	14,180
1⅛	33,320	16,660
1¼	41,480	20,740
1⅜	50,680	25,340
1½	61,240	30,620
1⅝	71,800	35,900
1¾	82,330	41,170
1⅞	96,640	48,320
2	105,520	52,760

(1-193)

Courtesy of Martin-Black Wire Ropes Ltd

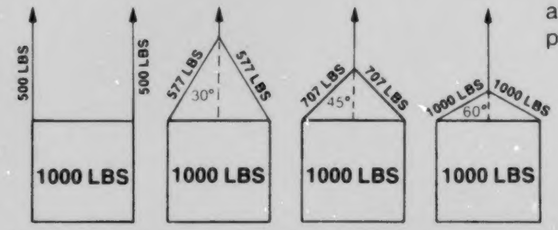
Inspecting Wire Rope Slings

Wire rope slings, like chains, should be inspected on a regular basis, although, because of their construction, they don't require as careful examination as chains. To inspect wire rope slings:

1. Look for broken outer wires and signs of stretching.
2. Check for kinks and twists. Badly kinked or twisted ropes should be discarded.
3. Check the eye for signs of failure at the outer end and at the crimped join.

Care and Use Of Wire Rope Slings

1. Hang up the slings when not using them.
2. Use shackles to connect sling eyes to lifting eyes.
3. Protect the rope with blocking or pads when it passes around sharp corners.
4. Don't pull slings from under loads because this causes unnecessary wear on the rope and can kink it.
5. Don't drop loads on slings or run over them with heavy equipment as crushing limits the service life of slings.
6. Whenever possible keep the sling lifting angle from the vertical to 45 degrees or less. Figure 1-194 shows the effects of sling angle on sling load. Note that once the angle reaches 60 degrees, double the amount of strain is put on the sling compared to lifting vertically.



(1-194) EFFECT OF SLING ANGLE ON SLING LOAD

RIGGING HARDWARE

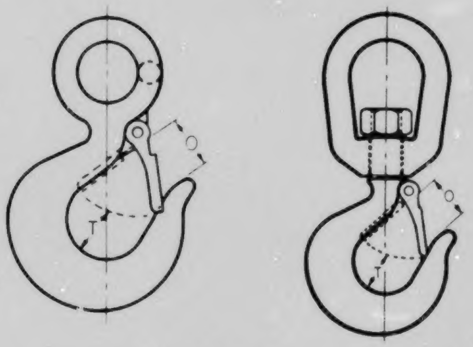
HOOKS

Common types of hooks are slip hooks, safety hooks, grab hooks, and choker hooks. An eye slip hook and a clevis slip hook are shown in Figure 1-195. Safety slip hooks in solid or swivel forms are also available (Figure 1-196). Figure 1-197 shows an eye grab hook and a clevis grab hook. A sliding choker hook is shown in Figure 1-198).

Slip hooks and grab hooks are generally used with chains, although sometimes slip hooks are attached to the eye of a sling such as on bridle slings. The clevis type of slip or grab hook is handy as it can be put on or taken off to suit the job. Choker hooks are made to slide on wire rope.

Inspection, Care and Use Of Hooks

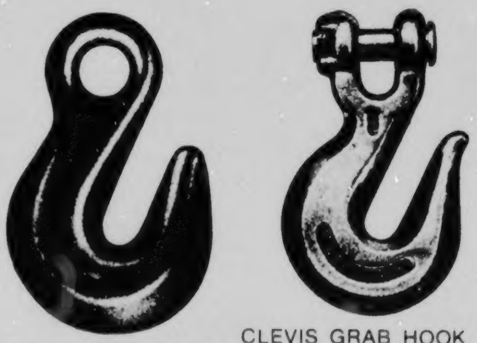
1. Critical inspection points for hooks are shown in Figure 1-199). Severely worn, twisted or spread hooks are unsafe and should be discarded.
2. Lift only in the saddle of the hook; don't lift at the point. The further the load is moved from the saddle to the point the less the hook is capable of lifting. For example, a hook at the point can carry only approximately 40% of its rated load.
3. Ensure that grab hooks are the correct size to fit the chain they are used with.
4. Whenever possible use hooks with safety catches.



SAFETY HOOK SWIVEL SAFETY HOOK

(1-196) SAFETY HOOKS

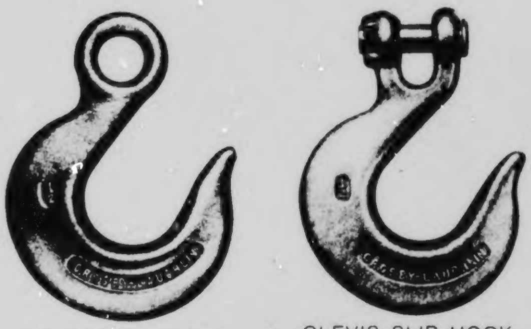
Courtesy of Martin-Black Wire Ropes Ltd



EYE GRAB HOOK CLEVIS GRAB HOOK

(1-197) GRAB HOOKS

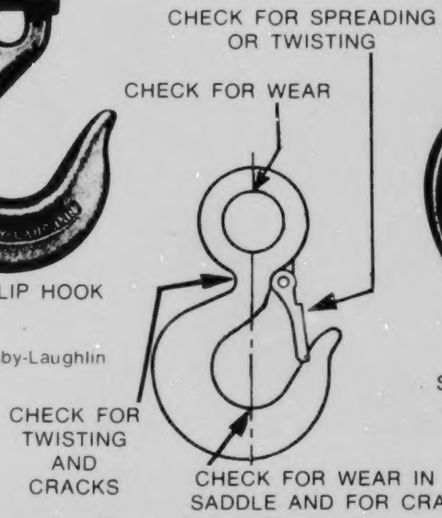
Courtesy of Crosby-Laughlin



EYE SLIP HOOK CLEVIS SLIP HOOK

(1-195) SLIP HOOKS

Courtesy of Crosby-Laughlin


CHECK FOR SPREADING OR TWISTING
CHECK FOR WEAR
CHECK FOR TWISTING AND CRACKS
CHECK FOR WEAR IN THE SADDLE AND FOR CRACKS

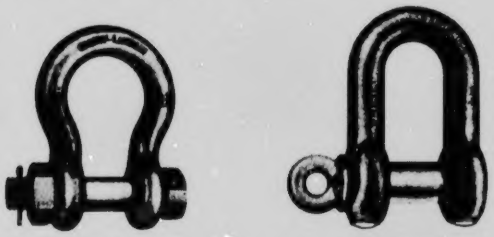
(1-199) INSPECTING HOOKS

(1-198)
SLIDING CHOKER HOOK

Courtesy of Crosby-Laughlin

SHACKLES

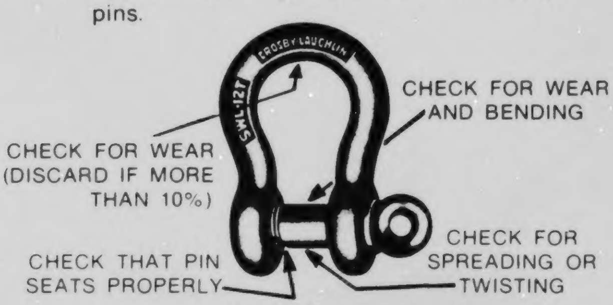
Shackles are used to couple a chain or sling to a lifting hook or to a load. Two common types of shackles are bow-type and D-type (Figure 1-200). The D-type is usually longer, whereas the bow-type is wider and will fit a larger lifting hook. Shackles are sized according to the diameter of the body of the shackle rather than pin diameter. Safe working loads of shackles depend on their size, e.g., a three-quarter inch diameter forged alloy steel shackle has a safe working load of four and three-quarter tons.


BOW-TYPE D-TYPE

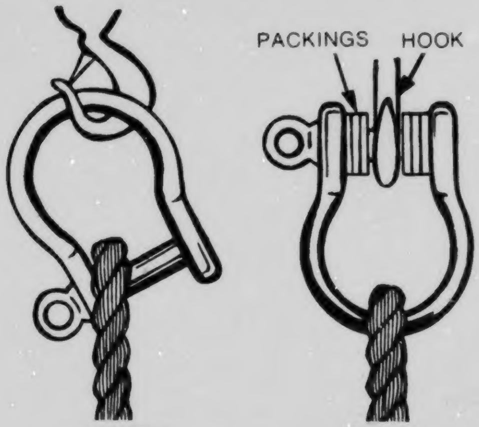
(1-200) SHACKLES
Courtesy of Crosby-Laughlin

Inspection, Care and Use Of Shackles

1. Figure 1-201 illustrates the critical inspection spots on a shackle.
2. Use only forged alloy steel shackles.
3. Don't use a bolt in place of a shackle pin as it may be of a lower grade steel and will bend.
4. Discard spread, twisted or bent shackles.
5. Loads must be centered on the shackle. If need be use washers or spacers to center a load on the pin (Figure 1-202). If the load is lifted off-center, the shackle has reduced lifting capacity, and it will likely be damaged.
6. Fully install screw pins.
7. Lock all round pin shackles with cotter pins.


CROSBY LAUGHLIN
SWL 12T
CHECK FOR WEAR AND BENDING
CHECK FOR WEAR (DISCARD IF MORE THAN 10%)
CHECK FOR SPREADING OR TWISTING
CHECK THAT PIN SEATS PROPERLY

(1-201) Courtesy of Crosby-Laughlin



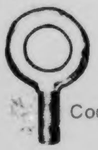
WRONG
LOAD OFF CENTER

RIGHT
LOAD CENTERED

(1-202)

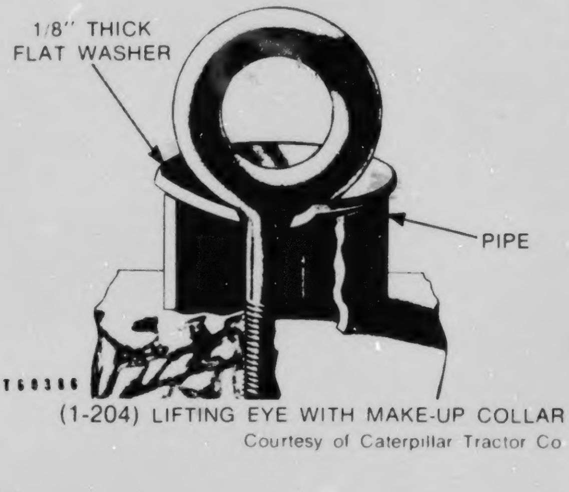
LIFTING EYES

Lifting eyes are used to lift odd shaped parts. Components such as transmissions, cylinder heads and engine blocks often have conveniently taped holes for lifting eyes to be threaded into. Lifting eyes are available in a variety of thread sizes but generally only in N.C. thread. They are made from forged alloy steel and are most useful when equipped with shoulders or collars. Plain eye bolts (Figure 1-203) are okay for vertical lifts but when angle loaded they are subject to bending and have a reduced safe carrying load. A pipe sleeve with a thick washer on the top (Figure 1-204) will support a plain eye bolt when a shoulder eye bolt is not available.



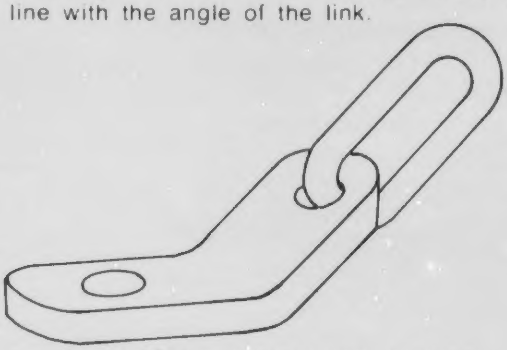
(1-203)
PLAIN EYE BOLT

Courtesy of Owatonna Tool Company



(1-204) LIFTING EYE WITH MAKE-UP COLLAR
Courtesy of Caterpillar Tractor Co

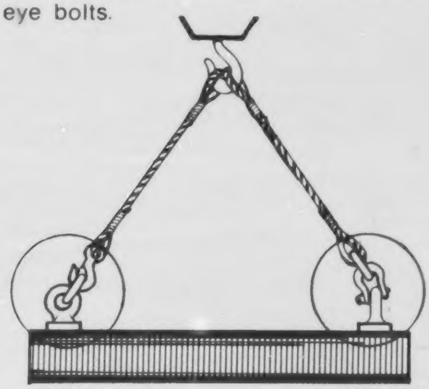
Bolt-on lifting eyes made for lifting light loads are also available (Figure 1-205). They are made of forged alloy steel and the link is permanently attached. The lift must be made in line with the angle of the link.



(1-205) BOLT ON LIFTING EYE

Use and Care Of Eye Bolts

1. The taped hole for the eye bolt should be of adequate depth: at least one and a half times the diameter of the bolt.
2. When putting an angle load on an eye, make sure that the load pulls in line with the eye rather than at right angles to it. Otherwise, the eye will bend (Figure 1-206). Shims may be necessary to line the bolt up and at the same time to keep it tight.
3. Always use a shackle with an eye bolt; never put the point of a hook into an eye bolt.
4. Don't run a sling through two eye bolts. Attach a separate sling to each bolt.
5. Angular loading is not recommended for plain eye bolts without shoulders.
6. Angle loading greater than 45 degrees from the vertical is not recommended with eye bolts.



RIGHT
PULLING IN LINE

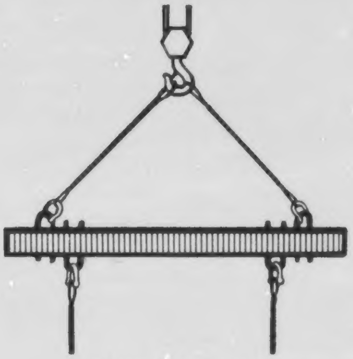
WRONG
AT RIGHT ANGLES

(1-206)

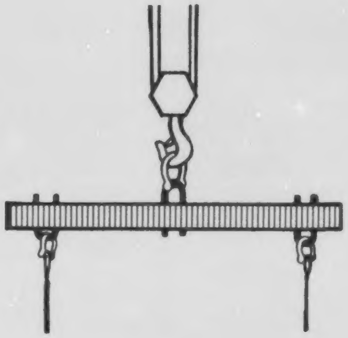
SPREADER AND EQUALIZER BEAMS

Spreader beams (Figure 1-207) balance long loads during lifting, preventing them from tipping, turning or sliding. Equalizer beams (Figure 1-207) equalize the load over the length of the object lifted.

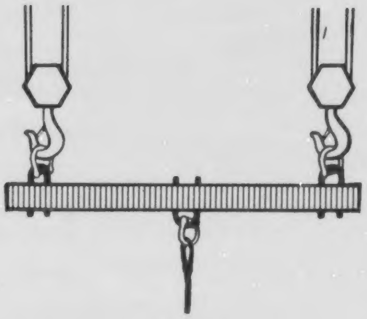
Spreader and equalizer beams are often made up in the shop, rather than purchased, and are used for jobs such as lifting heavy engines. Shop-made beams should have the lifting capacity marked on them, in addition to the job the beam is intended for.



SPREADER BEAM



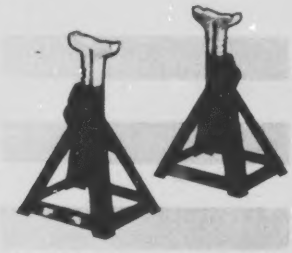
EQUALIZER BEAMS



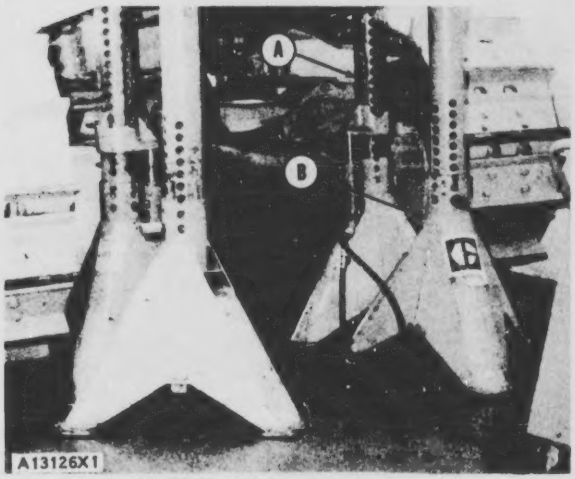
(1-207)

BLOCKING AND STANDS

Whenever raising a piece of equipment or a vehicle to work on it, proper blocking or stands must be used to support it. Both wood blocking and stands are acceptable for shop work, as long as they are heavy enough for the job. Examples of truck stands are shown in Figure 1-208 and equipment stands in Figure 1-209.

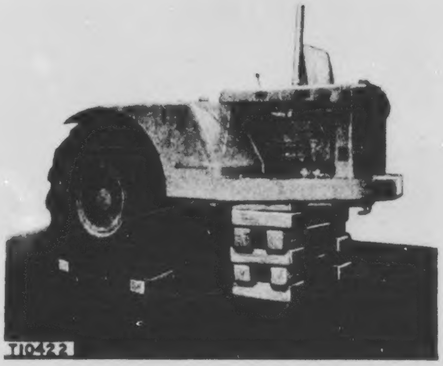


(1-208) TRUCK STANDS
Courtesy of Hein-Werner



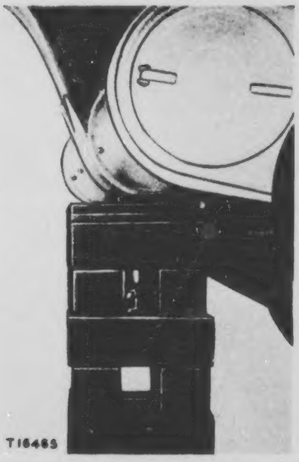
(1-209) EQUIPMENT STANDS
Courtesy of Caterpillar Tractor Co.

When wood blocking is used, select firm square blocks, and place them as shown in Figure 1-210. This arrangement of blocks is called bridging; it provides a wide, solid base for the machine. In this example note also how blocks have been placed at the front and rear of the tires to prevent the machine from rolling. Other examples of blocking are shown in Figure 1-211.



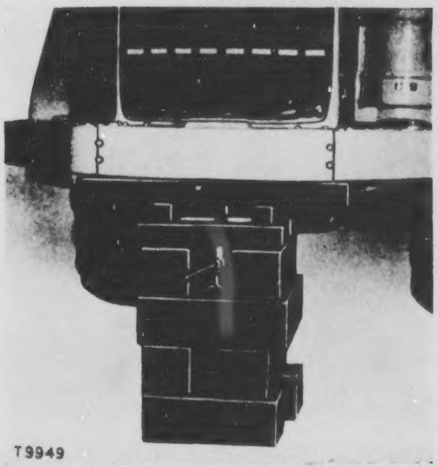
(1-210) BLOCK BRIDGING
Courtesy of Caterpillar Tractor Co.

In the field, if possible, move the machine or equipment to firm level ground before jacking and blocking. Make a bridging with wood blocks, the largest ones at the bottom to form a sound base.



BLOCKING UNDER THE SCRAPER DRAFT TUBE

(1-211)



BLOCKING THE FRONT OF THE TRACTOR
Courtesy of Caterpillar Tractor Co.

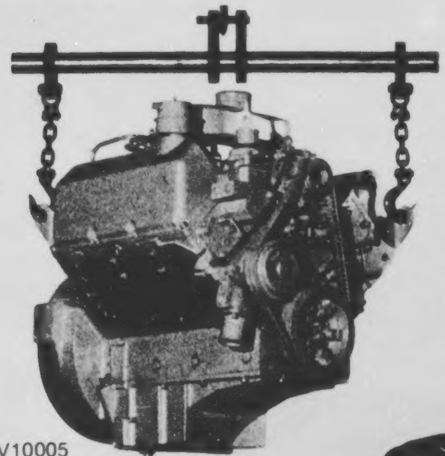
LIFTING PROCEDURES AND PRECAUTIONS

Lifting procedures and equipment depend on four factors:

- — the object to be lifted
- — its weight
- — the lifting and blocking material available
- — the decision to lift from above or jack from below

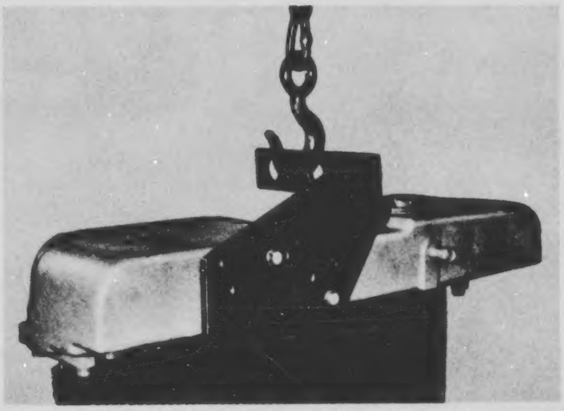
Good Practices When Lifting

1. Find the weight of the object to be lifted; service manuals are the best source for this information. The diesel engine shown in Figure 1-212 could weigh, with all its accessories, from 2000 to 4000 pounds. Note the equalizer beam and lifting brackets.

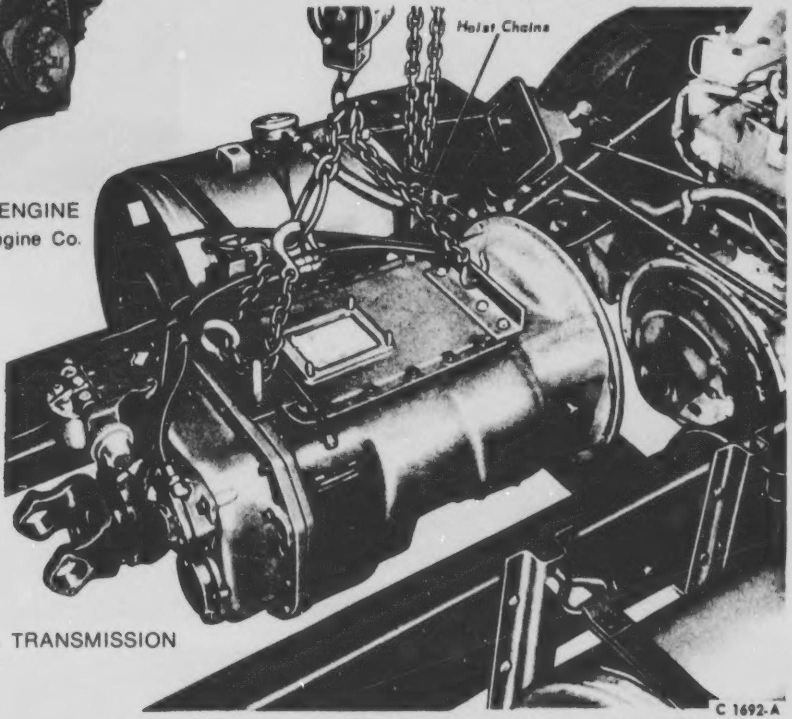


(1-212) LIFTING AN ENGINE
Courtesy of Cummins Engine Co.

2. If the center of gravity of the object being lifted is not in line below the hook, the load will shift. In Figure 1-213 the center of gravity of the transmission is not quite in line with the hook so a bolt has been installed through the chain link just underneath the hook. This bolt will prevent the transmission from shifting. Note the lifting eyes and the angle iron lifting bracket that have been installed for this lift. Lifting brackets can be easily made in a shop (Figure 1-214), or purchased from manufacturers or tool companies (Figure 1-215).



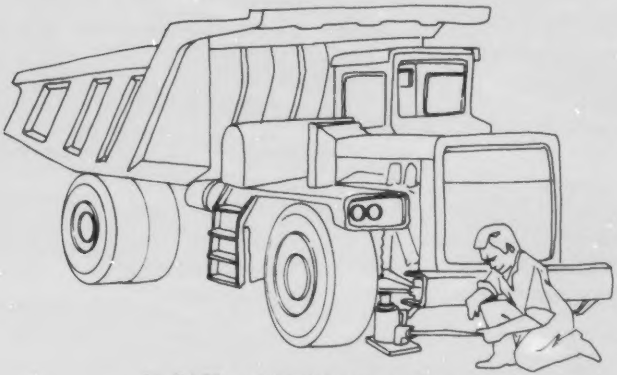
(1-214) SHOP-MADE LIFTING BRACKET
Courtesy of Caterpillar Tractor Co.



(1-213)
REMOVING OR INSTALLING TRANSMISSION

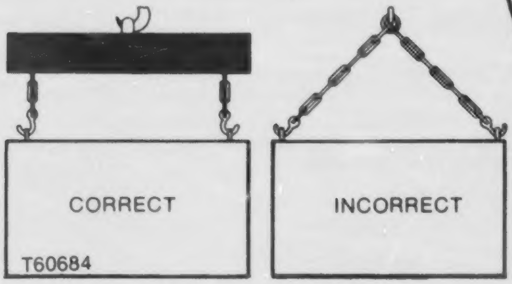
Courtesy of Ford Motor Company

(1-215) LIFTING BRACKET
Courtesy of Owatonna Tool Co.



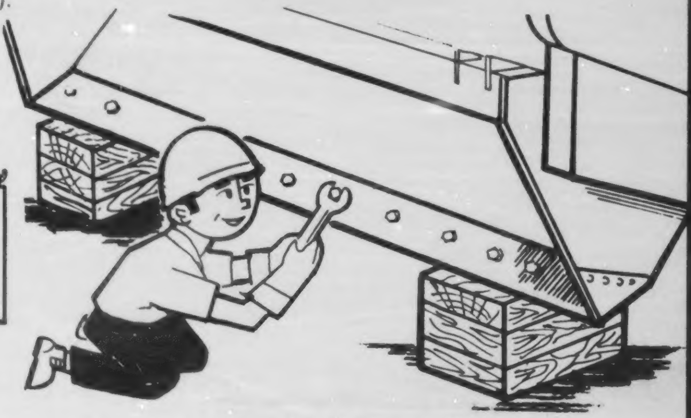
(1-216) HYDRAULIC JACK
Courtesy of Hein-Werner

3. Before using a hydraulic jack, be sure it has the capacity to lift the load (Figure 1-216).
4. When using a hydraulic jack make sure the threaded jack extension is well within its limit.
5. Use an equalizer bar to distribute the load whenever possible (Figure 1-217).



(1-217) LIFTING ENGINE
Courtesy of Caterpillar Tractor Co.

6. Never attempt to work on a machine or component while it is jacked or hoisted up. Block it or put it on stands first (Figure 1-218).
7. Never walk under a lifted object.
8. Lift an object only as high as necessary, then lower it as soon as possible. Never leave it suspended.
9. Always keep the load under control. If necessary tie a tag line on the load to prevent excessive swinging.
10. Keep your hands clear of sling pinch points when the sling tightens for the lift.
11. Keep others away from a load that you are lifting or lowering.
12. Never ride on a load while it is being raised or lowered.
13. Raise and lower objects slowly.
14. In a situation where lifting brackets or lifting eyes are not available and a chain must be wrapped around a component to lift it, be careful to place the chain so that it does not slip and does not apply pressure to accessory parts.



(1-218) SOUND BLOCKING
Courtesy of Construction Industry Manufacturer's Association

QUESTIONS — LIFTING AND BLOCKING

1. What are the three basic types of lifting equipment?
2. For safety, what must all overhead lifting equipment have?
3. Once a vehicle is jacked, what must be done?
4. What is the main disadvantage of chain compared to wire rope for lifting?
5. Why are chains better than slings for lifting irregular shaped objects?
6. On a two part sling, does the loading increase or decrease as the angle between the sling and load becomes less than 90 degrees?
7. The lifting angles on two or three part wire rope slings should be kept under ________ degrees.
8. True or False? Slip hooks and grab hooks are both made for use with wire rope slings.
9. The size of a shackle is given by:
   (a) the width of the bow
   (b) the length of the bow
   (c) the diameter of the material in the bow
10. When a shouldered lifting eye is not available, a plain eye can be used if:
    (a) it is large enough
    (b) it is screwed further into the casting
    (c) a shackle is used as well
    (d) a pipe sleeve and washer are used to support it and prevent it from bending
11. A taped hole for a lifting eye should have a minimum depth of:
    (a) two times the bolt diameter
    (c) one and one-half times the bolt diameter
    (c) three times the bolt diameter
    (d) at least equal to the bolt diameter
12. A spreader or equalizer bar made in a shop should:
    (a) be painted so it can be easily seen
    (b) have its lifting capacity marked clearly on it
    (c) have the job it was intended marked on it
    (d) both (b) and (c) are correct
13. Two acceptable methods of supporting raised machinery are ________ and ________.
14. When blocking is placed in a crisscross pattern, it is known as ________.
15. Where would you look to find the weight of a component?
16. When you discover a crack in a chain:
    (a) cut out the cracked link and join the chain up
    (b) make up a new link in the shop
    (c) discard the chain
    (d) ignore the crack
17. Name three things to look for when inspecting the chain.
18. If a wire rope sling has to pass over a sharp corner on the object it's lifting, what should be done?
19. True or False? Hooks are designed so that lifting is done on the tip of the hook.
20. When attaching a sling to a lifting hook, use a ________.

WELDING

WELDING AND CUTTING

Heavy duty mechanics use oxyacetylene equipment to cut materials for fabrication, for removing seized parts, and for removing welded parts. They may also do some basic flat welding and brazing, for example, when fabricating exhaust systems and repairing broken components on various types of equipment. Heavy duty mechanics, however, unless they have a welding certificate, should not consider themselves as qualified welders.

The purpose of this section is to give the essential information needed for safe handling, set up, and operation of oxyacetylene welding, cutting, and heating equipment.

CYLINDERS — HANDLING, STORAGE AND SAFETY

1. The storage and handling of oxygen and acetylene cylinders are governed by the Fire Marshal's Regulations. These regulations also specify the safety precautions that must be taken when welding and cutting. Although general precautions for the handling and storage of cylinders are given here, take the Fire Marshal's Regulations as the authority.
2. Be sure the cylinders contain the proper gas and are stored with like gas cylinders. Never mix unlike gas cylinders.
3. Protect the cylinders against the weather when stored outdoors, particularly against ice, snow, and direct rays of the sun.
4. Store empty cylinders separately from full cylinders, and mark the empty ones so they can be recognized.
5. Do not store cylinders close to hot surfaces such as radiators or stoves.
6. Be sure cylinder storage rooms are well ventilated.
7. Chain or fasten cylinders to a carrier, or to a fixed object, when in use.
8. Protection caps should be in place on the top of the cylinders when they are in storage and when they are being moved to and from the shop or storage area.
9. Always close the cylinder valves when the equipment is not in use.
10. Do not refer to oxygen as air or to acetylene as gas. Refer to them as oxygen and acetylene.
11. Handle cylinders carefully and never drop them. Use a cradle or a holder when lifting them with a crane. Never use a magnet to lift cylinders.
12. Be sure the cylinders are fastened so that they cannot move during transporting. Lift, rather than slide a cylinder from the vehicle and keep the cap in place.
13. Never roll cylinders or use them as rollers.
14. Keep oil and grease from the cylinder valves.
15. Store cylinders securely where they cannot fall or be struck by mechanical or other objects, and where they cannot contact salt or corrosive chemicals or fumes.
16. Cylinders should be kept in an upright position when in use and in storage.
17. Cylinders should be used in the order that they are received from the supplier.
18. Cylinders should not be placed in locations where sparks or flame from welding or cutting can contact them.
19. Extreme care must be taken to ensure that the arc from an electric welder never touches a cylinder.
20. Cylinders should never come into contact with bare electric wires.
21. To prevent serious explosions, oily and greasy substances must be kept from oxygen cylinders, valves, hoses and appurtenances.
22. Do not attempt to repair cylinder valves.
23. Make sure the valve is tightly closed when handling the cylinder. Do not remove the key from the valve while the cylinder is in use.
24. Remove a leaking cylinder into the open air at a safe distance from any type of flame.
25. Do not tamper with the fusible safety plug on acetylene cylinders.
26. Keep the top of acetylene cylinders away from tools and other objects.

HOSE AND CONNECTIONS

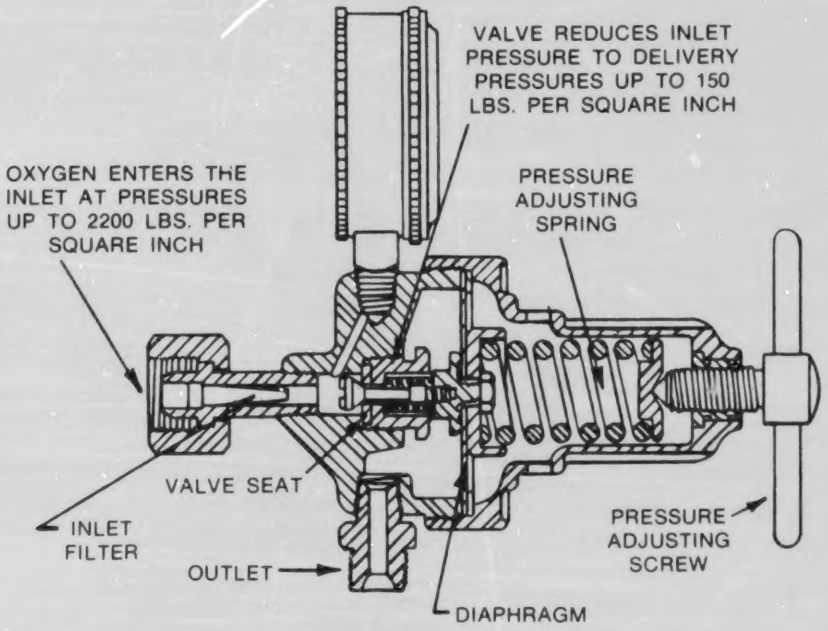
Hoses and connections carry the oxygen and acetylene at reduced pressures from the cylinders to the welding or cutting head attachment. Following are rules for safe use of hose and connections:

1. Use only first-grade quality hose.
2. Hose should be protected at all times against damage and misuse.
3. Hose should be placed so that it will not create a tripping or stumbling hazard.
4. Oxygen hose should be green and acetylene hose red.
5. Connections should be either the ferrule or the clamp type, capable of withstanding, without leakage, a pressure equal to twice the maximum delivery pressure of the pressure regulators provided.
6. Standard oxygen equipment has right-hand threads, and acetylene equipment left-hand threads. The connections must never be forced.
7. Hose should be frequently examined for leaks and defects.
8. Never use oil or grease to make connections.
9. Never use tape to repair a hose.

REGULATORS

The regulator is a device connected to the cylinder that reduces high pressure in the cylinder and maintains a constant working pressure. The basic principle of operation of a single stage regulator is that a spring, connected to a handle, exerts pressure on a diaphragm (see Figure 1-219). The diaphragm in turn is connected to a valve which controls the flow of gas from the cylinder through the regulator to the torch. When adjusting screw is turned in, the spring presses onto the diaphragm opening the valve and permitting the gas to flow at a certain pressure.

Any pressure higher than the set 'working pressure' tends to close the valve, thus reducing the flow and maintaining a constant working pressure. Only the stem, seat, and diaphragm are likely to need replacement on a single stage regulator.


VALVE REDUCES INLET PRESSURE TO DELIVERY PRESSURES UP TO 150 LBS. PER SQUARE INCH
OXYGEN ENTERS THE INLET AT PRESSURES UP TO 2200 LBS. PER SQUARE INCH
PRESSURE ADJUSTING SPRING
VALVE SEAT
INLET FILTER
OUTLET
PRESSURE ADJUSTING SCREW
DIAPHRAGM

(1-219) CROSS-SECTION OF SINGLE-STAGE OXYGEN REGULATOR

Two stage regulators are also available; they are actually two regulators in one in which the incoming gas pressure is first cut to an intermediate pressure and then to working pressure. They have greater accuracy of adjustment than single stage regulators and are recommended for precision cutting or welding, for heavy hand-cutting or welding, and for production machine welding or cutting operations.

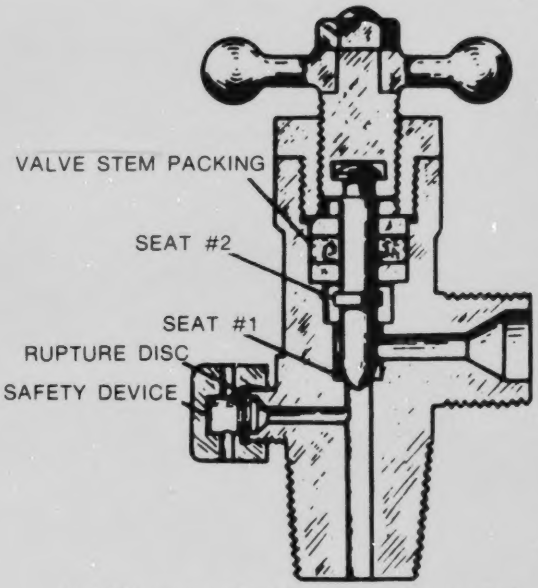
OXYGEN AND ACETYLENE CYLINDERS

Oxygen Cylinders

Oxygen cylinders are rented rather than sold, remaining the property of the oxygen manufacturer. At the slightest indication of weakening or sign of damage, the cylinders are withdrawn from service. Cylinders are made in a variety of sizes ranging from 55 cubic feet to 244 cubic feet. A large full cylinder weighs 152 pounds. The oxygen is compressed to 2700 psi at 20°C. As the temperature decreases the pressure decreases e.g., at −18°C oxygen pressure in the cylinder is 1780 psi.

The cylinder valve (Figure 1-220) is made to operate at high pressures. The double seat construction prevents leakage of oxygen around the stem when the valve is turned open all the way. The safety device incorporated in the valve, consists of a pressure or rupture disc which will burst and release the oxygen before the cylinder will rupture due to excessive heat. The valve outlet fitting is a standard male thread to which all standard made pressure regulators may be attached. Before attaching, the valve should be cracked (opened briefly and reclosed) to remove any dirt that may be lodged in the seat which might plug the regulator.

No attempt should be made to repair a damaged valve or seat. Notify the supplier.



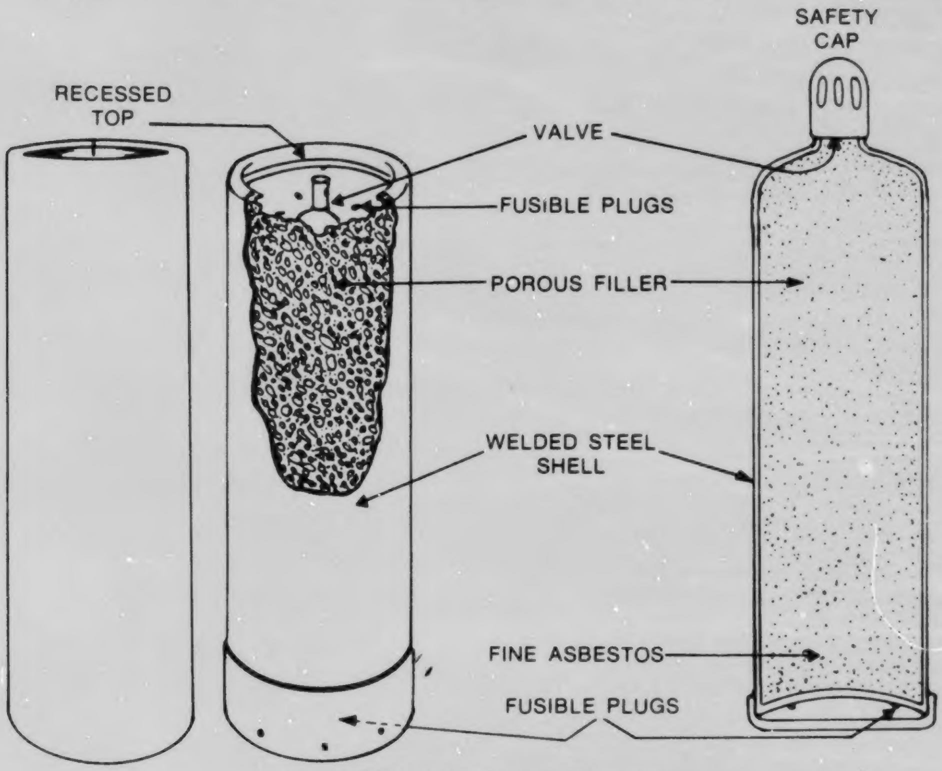
(1-220) HIGH PRESSURE OXYGEN VALVE

Liquid oxygen cylinders are another type of oxygen cylinder. They are mainly used where large quantities of oxygen are needed, having the advantage of reducing the size and weight of the container. These cylinders are refilled from a liquid oxygen tank wagon. Note that the oxygen in liquid oxygen cylinders is not under very high pressure, but it should be drawn from the tank at a fairly steady rate. Closing down the oxygen draw for a period of time will result in a pressure build-up which will activate the safety valve and release oxygen.

Acetylene Cylinders

Acetylene cylinders (Figure 1-221) are filled with a porous material such as asbestos, charcoal, balsa wood, etc.

The porous filler material is saturated with acetone, a special liquid which is straw-colored and belongs to the hydrocarbon family. It is flammable, quite volatile and has a strong odor. Acetone has the ability to absorb acetylene gas and is used in cylinders to make them safe at high pressures. One volume of acetone will absorb twenty volumes of acetylene gas at atmospheric pressure. This ratio increases as the pressure is increased. Acetylene cylinders have capacities to 350 cubic feet and a pressure of approximately 250 psi. Note that acetylene cylinders must be used in an upright position, otherwise the acetone will flow into the regulator, hose, and torch and plug them.



(1-221) ACETYLENE CYLINDER

OXYGEN AND ACETYLENE GASES

Oxygen

Oxygen (symbol O) is a colorless, odorless, and tasteless gas at ordinary temperatures and is slightly heavier than air. Oxygen forms approximately 20 per cent of the air we breathe, the remainder being composed of about 78 per cent nitrogen and the rest other gases. Oxygen cylinders contain pure oxygen.

Combustible items burn much more rapidly in pure oxygen than in air. Steel is not considered a combustible material, but when heated red-hot and oxygen is applied it will burn quite rapidly, reducing the reacted metal to iron oxides. Oxyacetylene flame-cutting is a controlled burning process. Oxygen is always a potential danger because it tends to speed up the combustion of known flammable materials, and combines readily and often violently with materials not generally considered combustible.

Acetylene

The chemical symbol for acetylene is C_2H_2, which means that an acetylene molecule is composed of two atoms of carbon and two atoms of hydrogen. It is flammable and burns within a range of 3% acetylene and 97% air to 87% acetylene and 13% air.

Acetylene gas is colorless, but has a strong pungent odor. Thus as little as one per cent acetylene in the air can be smelled. Acetylene is explosive. If any is smelled extinguish open flames and ventilate the room.

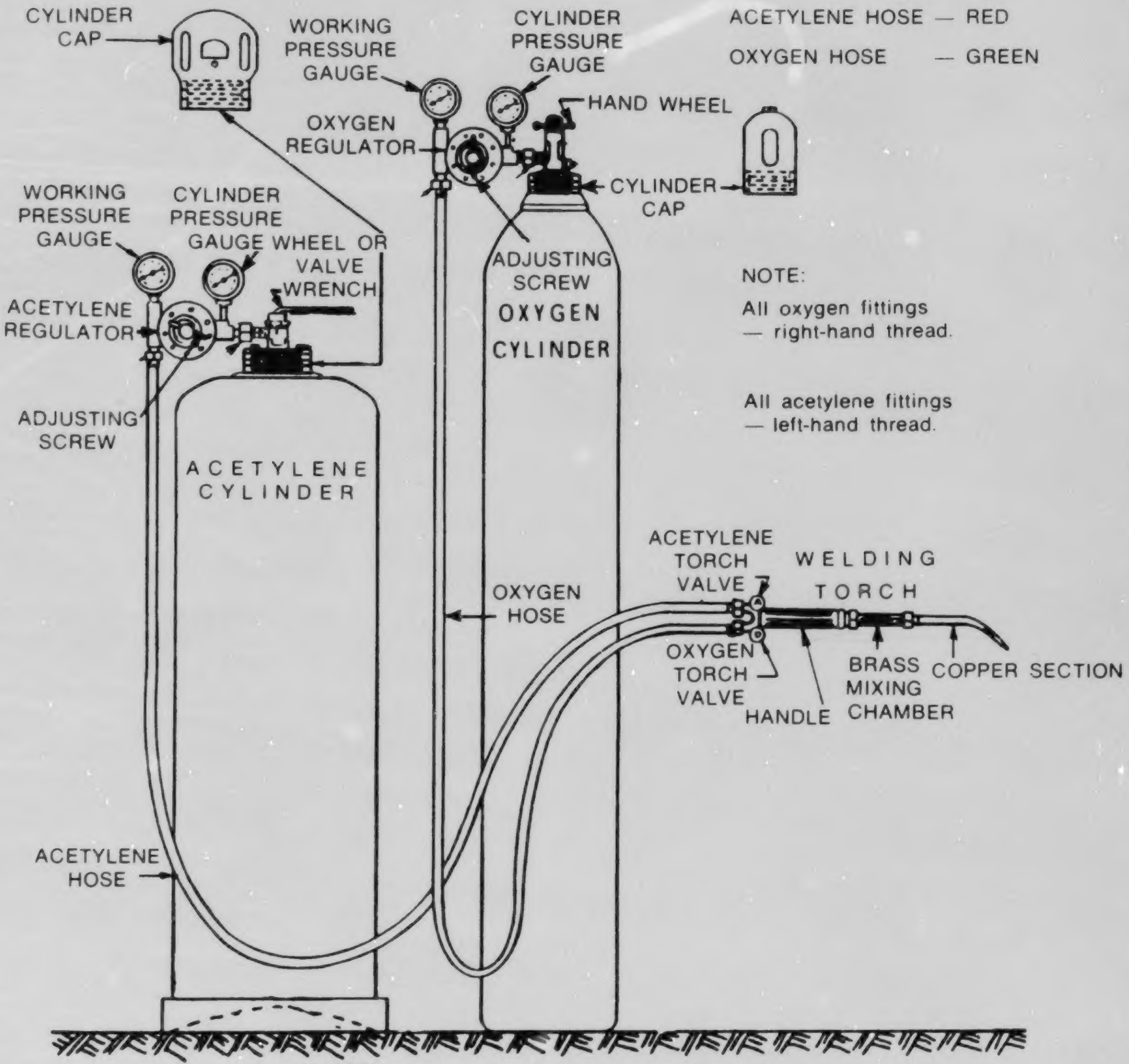
Acetylene is an unstable compound, that is, it has a tendency to break down or undergo a chemical change without much provocation. When this occurs, acetylene is said to have reached its critical point. The critical point of acetylene is 28 psi pressure at 21°C. At this point, acetylene breaks down into its components (carbon and hydrogen), releasing its endothermic heat, which usually results in spontaneous ignition. In other words, it explodes. The critical pressure is affected by the temperature of the gas. If the temperature is higher than 21°C the pressure at which the acetylene becomes critical will be lower than 28 psi. Thus it is understandable why the pressure in the acetylene hose and torch is always kept below 15 psi.

Fittings on acetylene lines must be made of yellow brass, iron, or steel. Never use copper or red brass fittings or tubing because the acetylene gas will react with the copper and form a residue that may cause an explosion at the slightest shock.

Weighing is the only accurate method of determining the amount of acetylene that has been used on a job or is left in a cylinder. One pound of acetylene gas equals 14.5 cubic feet at 21 C. Thus, if you multiply the weight of gas by 14.5 you have the cubic foot content of acetylene in the tank. The weight of the cylinder including the acetone content is stamped on the cylinder.

WELDING TORCHES

A typical welding torch of the type heavy duty mechanics are likely to use is shown in Figure 1-222. Its basic components are the acetylene torch valve, the oxygen torch valve, the handle, the brass mixing chamber, and the tip. Note also that the acetylene hose (red) is connected to the acetylene valve on the welding torch and that the oxygen hose (green) is connected to the oxygen valve on the torch. It is difficult to confuse these hoses and valves because all components of the acetylene systems have left-hand threads, while those on the oxygen system have right-hand threads.

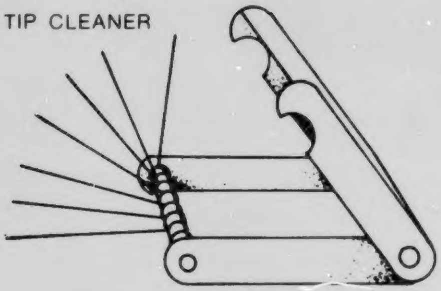

CYLINDER CAP
WORKING PRESSURE GAUGE
CYLINDER PRESSURE GAUGE
ACETYLENE HOSE — RED
OXYGEN HOSE — GREEN
HAND WHEEL
OXYGEN REGULATOR
CYLINDER CAP
WORKING PRESSURE GAUGE
CYLINDER PRESSURE GAUGE
WHEEL OR VALVE WRENCH
ADJUSTING SCREW
OXYGEN CYLINDER
NOTE:
All oxygen fittings — right-hand thread.
All acetylene fittings — left-hand thread.
ACETYLENE REGULATOR
ADJUSTING SCREW
ACETYLENE CYLINDER
ACETYLENE TORCH VALVE
WELDING TORCH
OXYGEN HOSE
OXYGEN TORCH VALVE
HANDLE
BRASS MIXING CHAMBER
COPPER SECTION
ACETYLENE HOSE

(1-222) OXYACETYLENE WELDING SET-UP

Cleaning Tips

The tips of welding torches must be kept clean and in good condition. Tip cleaners or drills are used for this purpose. The procedures for cleaning a torch tip with a tip cleaner are given below:

1. Select a cleaner needle one size smaller than the orifice in the tip. Do not force a larger cleaner needle into the orifice (Figure 1-223).
2. The up-and-down motion with the cleaner needle has to be straight to prevent flaring the orifice.
3. After withdrawing the cleaning needle, open the oxygen valve slightly to blow out any dirt.



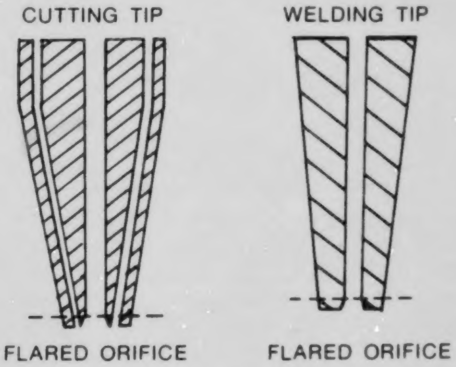
(1-223)

To clean a torch tip using a drill:

Select the correct size of drill, (do not use a drill that is larger than the orifice). Small drills are very brittle and care must be taken not to apply too much pressure nor to bend them sideways because they will break in the orifice and create other problems.

If orifices on welding or cutting tips become flared they will not perform properly. To recondition flared orifices, remove about 1/16th inch of the tip (see the dotted line in Figure 1-224) using a file or emery cloth so that the face is square to the axis of the tip.

Remove with a drill the slight burr left by the filing.



(1-224) REPAIRING FLARED ORIFICES

Tip Sizes

The following table is a guide to the selection of tip sizes, oxygen and acetylene pressure, and tip-cleaner size. Note the relationship between the tip size and the recommended pressure. For more specific information, consult torch manufacturers' instructions.

Tip Number	Thickness Of Metal (Inches)	Oxygen Pressure (Pounds)	Acetylene Pressure (Pounds)	Tip Cleaner Size
00	1/64	1	1	7
0	1/32	1	1	8
1	1/16	1	1	10
2	3/32	2	2	14
3	1/8	3	3	18
4	3/16	4	4	22
5	1/4	5	5	26
6	5/16	6	6	30
7	3/8	7	7	34
8	1/2	7	7	37
9	5/8	7½	7½	42
10	3/4 & up	9	9	45

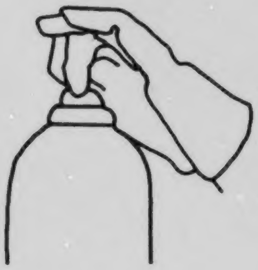
Correct Use Of Welding Torches

1. Goggles must be worn at all times when welding or cutting. There are many different types of goggles. Some have darker glass than others, and some are designed for use by workers who normally wear glasses. Never depend on ordinary glasses to provide eye protection when welding. Leather gloves are essential to protect the welder from flying sparks and hot materials. Leather aprons should also be worn when welding.
2. Torches should be lit by a friction lighter, and never by a match.
3. When torches are changed or welding is stopped for longer than about five minutes, all cylinder valves should be closed.
4. A clear, unobstructed space should be maintained between the working point and the cylinders so the pressure regulators can be reached quickly.
5. Torches should not be relit from hot metal, especially when operating in a small confined space; because if the gases do not light instantly, ignition may be violent.

SET UP OXYACETYLENE EQUIPMENT

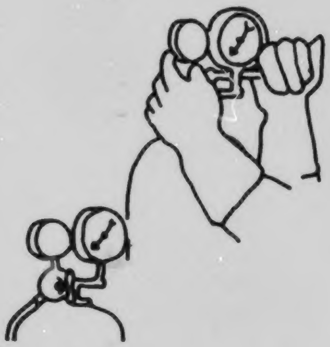
See Figure 1-225 for illustrations of these procedures.

1. Secure cylinders in an upright position.
2. Stand clear and crack cylinder valves to clean out dirt and water.
3. Attach regulators making certain the regulator adjusting screws are turned out, loose.
4. Attach hoses to regulators.
5. Stand clear and open cylinder valves slowly. Acetylene: one and one-quarter turns maximum, although one-half turn is usually sufficient. Oxygen: all the way.
6. Turn in the regulator adjusting screw. Blow out the hoses and turn out the adjusting screw again.
7. Attach the torch handle.
8. Attach the proper size tip.
9. Set the correct working pressures by turning in the regulator adjusting screws until the working pressure gauge registers the correct pressure.
10. Test for leaks (see information below).
11. Open the acetylene needle valve on the torch handle one-quarter turn and ignite the gas with a spark lighter. Adjust for a smokeless flame.
12. Open the oxygen needle valve on the torch handle and adjust until you get the desired flame.



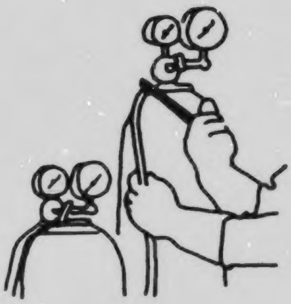
1

"CRACK" OXYGEN CYLINDER VALVES . . . THIS BLOWS OUT ALL DUST WHICH MAY BE PRESENT



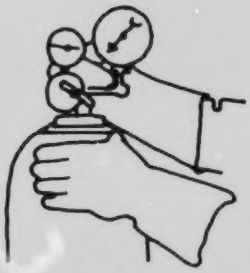
2

ATTACH REGULATORS. SET THE NUTS UP SNUGLY WITH A WRENCH, NOT "PLIERS". BEWARE OF GREASE.



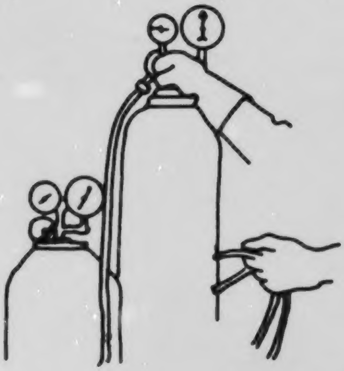
3

ATTACH HOSE TO REGULATORS. BE SURE ALL CONNECTIONS ARE CLEAN AND GAS TIGHT.



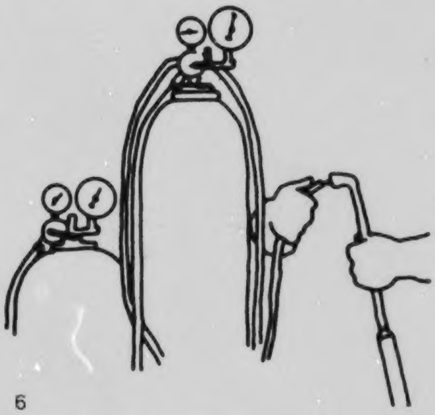
4

RELEASE REGULATOR ADJUSTING SCREWS AND OPEN CYLINDER VALVES.



5

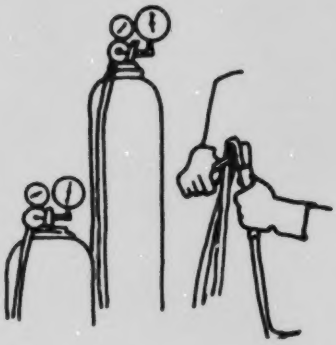
TURN JUST ENOUGH GAS TO BLOW OUT HOSE.



6

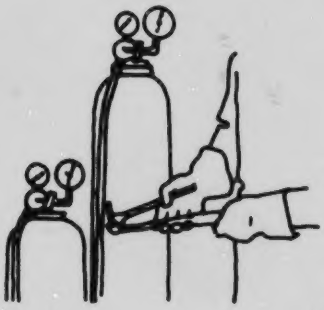
OPEN NEEDLE VALVES OF TORCH . . . INSERT OXYGEN HOSE IN TORCH HEAD AND TURN ON A LITTLE OXYGEN TO BLOW OUT INTERIOR OF TORCH.

(1-225)



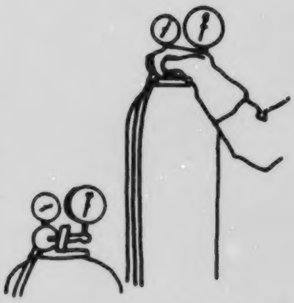
7

CONNECT HOSE TO TORCH. TAKE CARE TO ATTACH OXYGEN HOSE TO OXYGEN INLET ON TORCH. MAKE CONNECTIONS CLEAN AND GAS TIGHT.



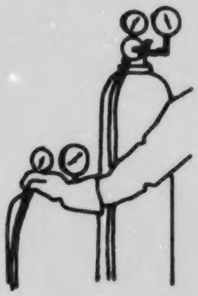
8

INSERT TIP IN TORCH HEAD AND TIGHTEN WITH WRENCH. BE SURE THE TIP IS CLEAN. USE JUST ENOUGH PRESSURE TO MAKE TIP GAS TIGHT. CONSULT MANUFACTURER'S CHART WHEN SELECTING TIPS.



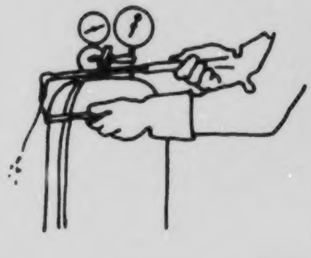
9

OPEN ACETYLENE NEEDLE VALVE AND TURN REGULATOR ADJUSTING SCREW UNTIL DESIRED ACETYLENE PRESSURE IS OBTAINED.



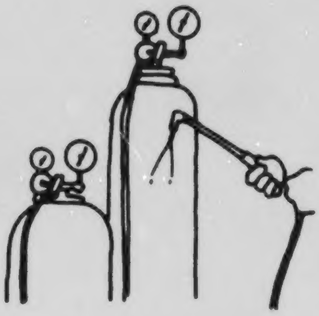
10

OPEN NEEDLE VALVES OF TORCH AND TURN OXYGEN REGULATOR ADJUSTING SCREW UNTIL DESIRED WORKING PRESSURE IS INDICATED THEN CLOSE OXYGEN NEEDLE VALVE.



11

IGNITE ACETYLENE WITH TORCH LIGHTER. AVOID USE OF MATCHES OR OPEN FLAME.



12

OPEN OXYGEN NEEDLE VALVE AND ADJUST FOR NEUTRAL.

(1-225)

Testing For Leaks

Before using oxyacetylene equipment, pressurize it by opening the cylinder valves and turning the regulator adjusting screw until the desired working pressure is shown on the low pressure gauge. Close the cylinder valves and observe the high pressure gauge. A leak will be indicated by a drop in pressure (make sure the valves on the torch handle are closed properly).

If a leak is present locate it by using soap suds made from a non-detergent soap (ivory) brushed on the fittings. Hoses may be tested by immersing them in water. Bubbles will indicate a leak. Never test for a leak with an open flame (Figure 1-226). Leaks should be properly repaired before using the equipment.

. . . IF TORCHES, HOSE OR REGULATORS LEAK, REPORT THEM TO YOUR PUSHER OR FOREMAN IMMEDIATELY. THIS IS ESPECIALLY IMPORTANT IF THE LEAK IS IN THE ACETYLENE GAUGE OR CYLINDER . . .

. . . NEVER LOOK FOR A LEAK WITH A MATCH OR OTHER LIGHT . . .

(1-226) LEAKS

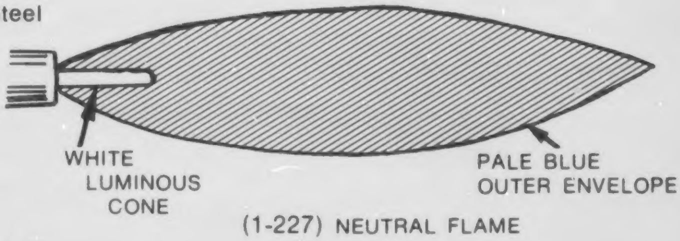
Oxyacetylene Flames

Three types of flames (Figure 1-227) are produced by adjusting the needle valves controlling the amounts of acetylene and oxygen being burned.

1. **Neutral Flame** — this is the ideal flame for welding or cutting steel. The ratio of acetylene and oxygen supplied to the torch is approximately 1 : 1. Melted steel flows easily and is clear and clean.

   Main Use — Cutting
   — Fusion welding of mild steel
   — Copper
   — Cast Iron

   Temperature — 3260°C. approximately



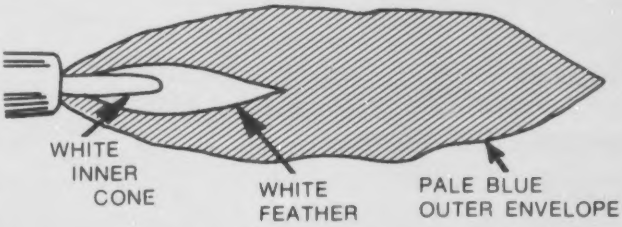
(1-227) NEUTRAL FLAME

2. **Reducing Flame — carburizing, carbonizing, excess acetylene.**

   More acetylene is supplied to the torch than the 1 : 1 ratio, producing an inner cone with a feather. The length of the feather indicates the amount of acetylene and is expressed in relation to the inner cone, e.g., "three times reducing" means that the white feather is three times the length of the inner cone. When steel is melted the puddle is boiling and not clear.

   Main Use — Aluminum welding, aluminum brazing, fusion welding of stainless steel, silver brazing and hard surfacing

   Temperature — 2980°C to 3200°C approximately



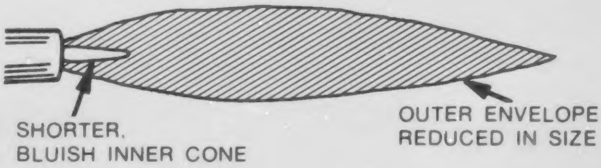
(1-227) REDUCING FLAME

3. **Oxidizing Flame — excess oxygen**

   More oxygen is fed to the torch for this type of flame than the 1 : 1 ratio of the neutral flame, producing a shorter, more bluish cone and somewhat shorter outer envelope. Melting steel with this flame produces excessive foaming and sparking of the metal.

   Main Use — Braze welding: Fusion welding of manganese

   Temperature — Maximum 3480°C approximately



(1-227) OXIDIZING FLAME

SHUTTING OFF OXYACETYLENE EQUIPMENT

When welding or cutting is stopped, first close the blowpipe acetylene valve, then the blowpipe oxygen valve. (Acetylene is on and off first.) If the welding or cutting is to be stopped for considerable periods of time such as for lunch or over night, the cylinder valve should be closed and all gas pressures released from the regulators. Take the following steps:

1. Close the oxygen cylinder valve.
2. Open the blowpipe oxygen valve to release all pressure from the hose and regulator.
3. Turn out the pressure-adjusting screw of the oxygen regulator.
4. Close the blowpipe oxygen valve.
5. Close the acetylene cylinder valve.
6. Open the blowpipe acetylene valve to release all pressure from the hose and regulator.
7. Turn out the pressure-adjusting screw of the acetylene regulator.
8. Close the blowpipe acetylene valve.

Note that the acetylene and oxygen pressures should not be released simultaneously, and care should be taken that the release of acetylene does not create a fire hazard.

HEATING

The oxyacetylene flame is a useful tool for a variety of heating operations. Metals will soften and become pliable when heated. Heating may be used to straighten or bend bars and angles. Once heated, the straightening or forming operation of the metal is done by external force. The torch, whether a regular welding torch or a specially designed heating torch such as a rose bud, should be moved constantly to avoid overheating a small area and possibly melting the metal.

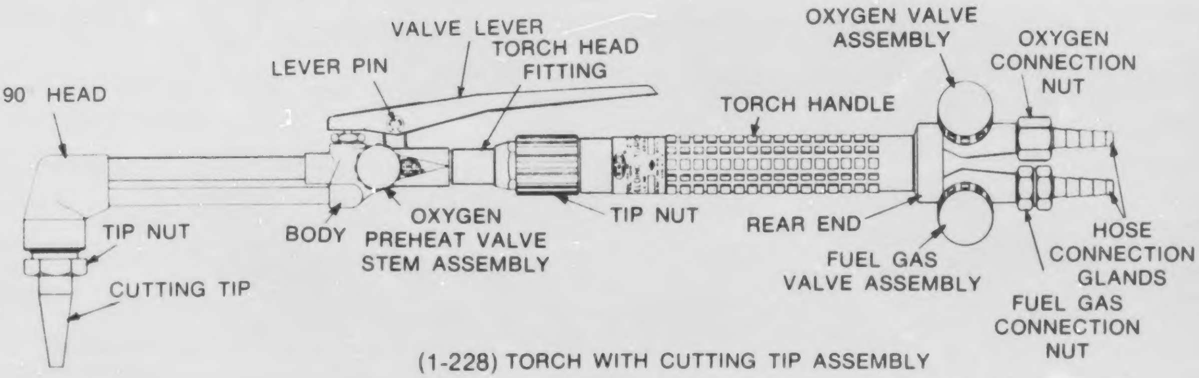
Heating has numerous applications in heavy duty shops. Two examples are heating seized nuts or studs to help in removing them, and heating large press-fit parts for ease of removal and installation.

When using heating equipment be careful not to overheat parts and not to damage parts adjacent to the one being heated. Set the regulator pressures according to tip size and do not hold the tip too close to the work as this could cause a backfire (see upcoming information on flashbacks and backfires).

FLAME-CUTTING

Flame-cutting is accomplished by rapid oxidation of combustion of heated steel when a jet of pure oxygen from a cutting torch is directed against it. The steel is cut by first heating a small area to the kindling temperature with preheating flames, then directing a jet of oxygen against the preheated area.

To prepare the welding torch for flame-cutting, remove the welding tip and the tip nut and attach a cutting torch assembly, as shown in Figure 1-228.



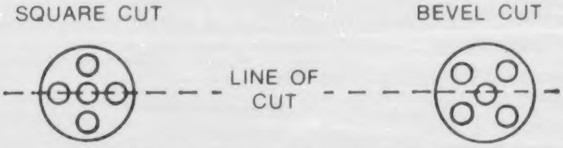
(1-228) TORCH WITH CUTTING TIP ASSEMBLY

Courtesy of Air Reduction Canada Limited

CUTTING TORCH TIPS

Cutting tips are interchangeable end pieces for cutting torches that contain openings for the preheating flame and for the cutting oxygen stream. Tips are supplied in a variety of sizes and styles to meet different cutting requirements. Torch manufacturers supply their own range of tips and charts that correlate tip sizes with material thickness, recommended pressures for acetylene and oxygen, and anticipated consumption of oxygen and acetylene in cubic feet per hour. For example, one manufacturer recommends that their L-2 tip be used to cut metal one to one and a half inches thick at an acetylene pressure of 5 psi and an oxygen pressure of 50 psi. This cutting process will consume 15.3 cubic feet of acetylene per hour and 150 cubic feet of oxygen.

For satisfactory cutting, tips must be clean and in good condition (see the information earlier on cleaning and filing tips). Note that cutting tips can be adjusted to produce a desired line of cut as illustrated in Figure 1-229.



(1-229) CUTTING TIP ADJUSTMENT

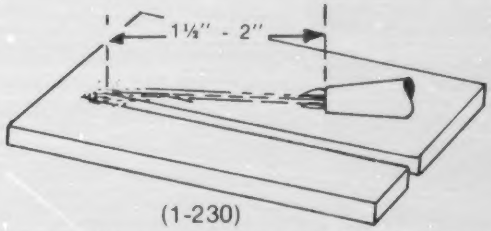
Cutting Procedures

Factors affecting the quality of a cut:

- Size of cutting tip (opening)
- Oxygen cutting pressure
- Speed of travel
- Material thickness
- Type of material
- Surface condition
- Amount of preheat
- Angle of cutting stream to surface
- Condition of cutting stream opening
- Condition of the end of cutting tip

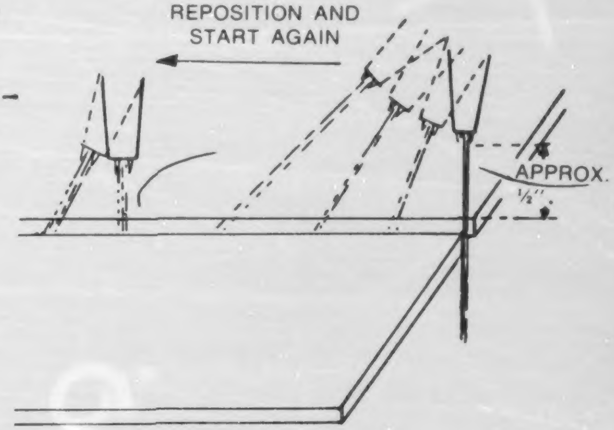
Cutting Thin Metals (less than 3/16" thick)

- Use the smallest cutting tip available.
- Reduce cutting oxygen pressure to 15 psi.
- Hold the torch at a very flat angle about 1½" to 2" away from the surface of the metal (Figure 1-230).
- Complete the cut as quickly as possible to avoid undue melting of the metal.



(1-230)
CUTTING TORCH DISTANCE FROM THE METAL

- An alternative cutting technique can be used to overcome difficulties in following a straight-line (Figure 1-231). Instead of running the torch straight make an arc while keeping the torch in the same relative position. However, only cuts of short length can be accomplished with this technique.



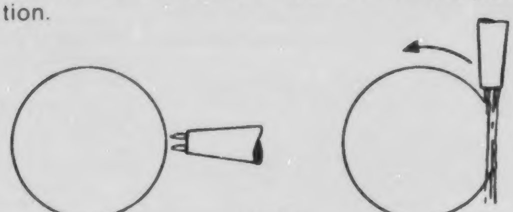
(1-231)
ARCING TECHNIQUE FOR SHORT LENGTH CUTS

Cutting Medium Thickness Metals (3/16" to 1 1/2")

- Hold the torch directly above the cutting line approximately 1/4 inch to 1/2 inch from the metal (depending upon the length of the preheat flame).
- Release the cutting oxygen stream only when the metal has reached proper preheat temperature.
- Tilt the torch slightly to direct the tip toward the forward line of the cut.

Cutting Rounds

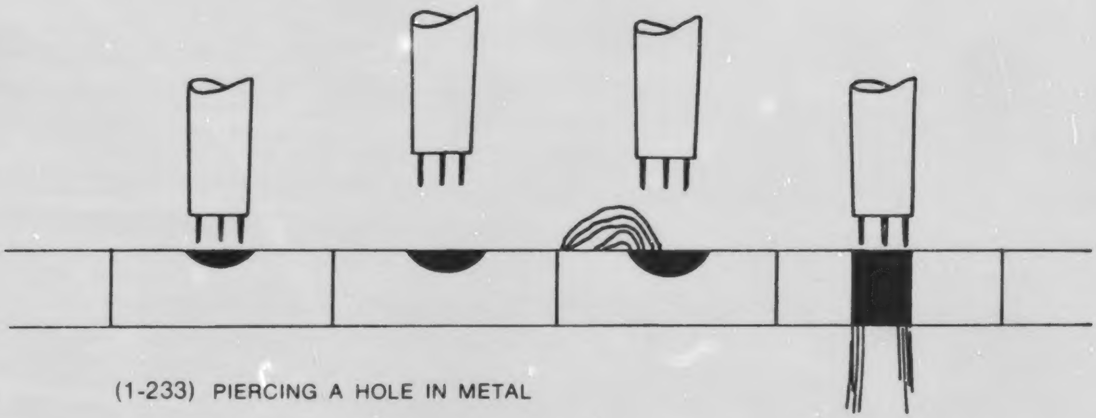
The technique for cutting rounds involves holding the torch perpendicular to the work for preheating and then following the outline of the round (Figure 1-232). A method of starting the cut is to raise a chip in the metal with a chisel (or by welding on a drop of metal), and to commence the cut on this raised portion.



(1-232)

Piercing Holes Through Metal

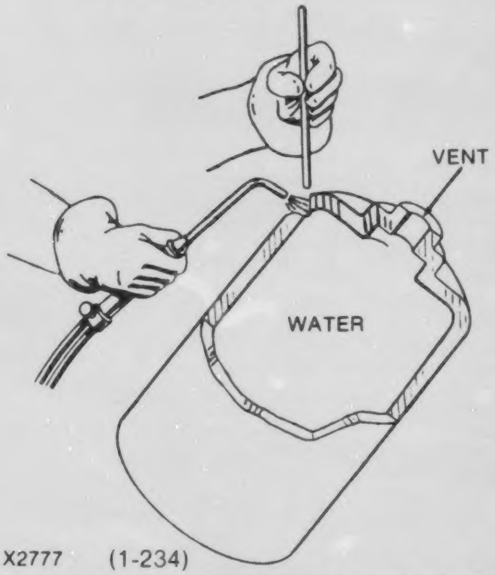
Since piercing holes requires a great deal of heat, choose a tip that is at least one size larger than the one recommended for the thickness of the metal. Hold the torch perpendicular to the work until preheating is achieved, then turn the oxygen jet on very gradually (Figure 1-233). As the cutting oxygen is fed, draw the tip back from the work just enough to ensure that the slag is not blown back into the tip openings.



(1-233) PIERCING A HOLE IN METAL

To Prevent Fires and Explosions

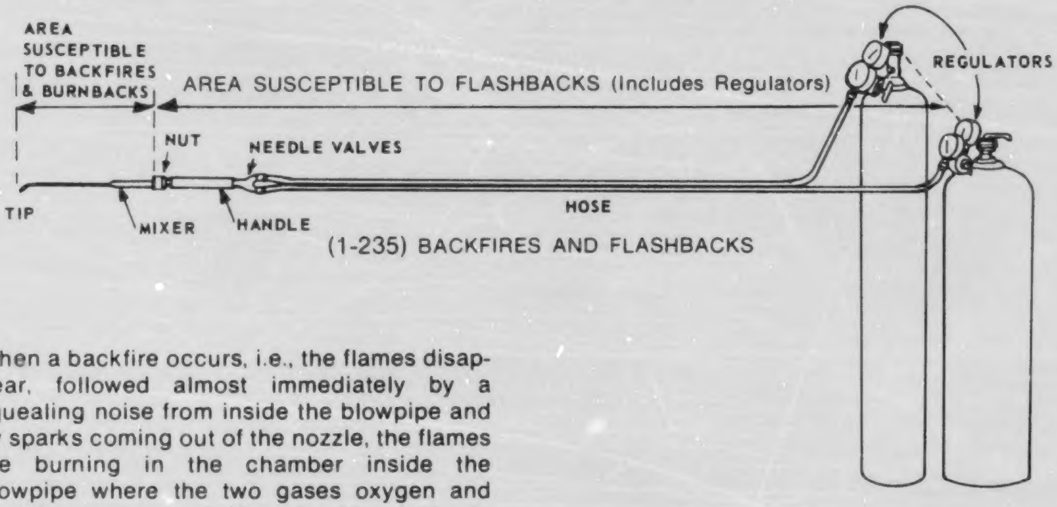
1. Keep flames and sparks away from cylinders and hose.
2. Keep protective equipment dry and free of oil. Take care that your own clothing is not oily and that pockets and cuffs are not open and ready to receive sparks or hot slag.
3. Move the job, if possible, to an area free of combustibles. Never work near explosive atmospheres. Avoid paint spray rooms, dip tanks, storage areas, ventilators.
4. If possible move combustibles at least 30 to 40 feet away from the job. Sweep the floor before lighting the torch. Wet down wooden floors.
5. Cover combustibles with fire resisting shields or covers, if they cannot be moved. Covers should be large enough to completely shield the material and be tight enough to prevent sparks from going under, over, or between the covers to the material. Use heat resisting asbestos shields to protect nearby walls, ceilings and floors.
6. Use stand-by watchers equipped with suitable fire extinguishers where the risk of fire is great.
7. Inspect the area on completion of the job to make sure that it is free of sparks, glowing embers and flames. Where there is a possibility that a smoldering fire may have been started, a watcher should be assigned to inspect the area for half an hour after work has been completed, or as long as is necessary to ensure that there is no outbreak of fire.
8. Take special precautions with oxygen:
    - (a) Never use oxygen to dust off clothing or work. A spark will cause clothing in an oxygen atmosphere to burst into flame immediately. If your clothing becomes contaminated with oxygen don't weld or cut for at least 15 minutes.
    - (b) Never use oxygen in pneumatic tools, in oil preheating burners, to start engines, to blow out pipelines, to create pressure in a container, or anywhere, as a substitute for compressed air or other gases.
9. Welding areas should be properly ventilated. Make sure that oxygen concentrations above normal cannot develop in the work area:
    - (a) Do not bring cylinders into confined spaces.
    - (b) Also if possible, light the torch outside, and bring it in when lit.
    - (c) Avoid oxygen leaks in enclosed spaces. Do not leave torches in enclosed spaces when not in use.
    - (d) Never use oxygen for ventilation, i.e., never try to replace atmospheric oxygen consumed during a welding or cutting operation. Ventilate with air.
10. When working on tanks and containers:
    - (a) Be familiar with standard practices for welding containers.
    - (b) Don't weld or cut containers such as drums, barrels, tanks, until you know there is no danger of fire or explosion.
    - (c) Don't depend on your eyes or nose to decide if a closed container is safe to weld or cut. A very small amount of residual flammable gas or liquid can cause a serious explosion. Find out what was in the container or use an explosimeter.
    - (d) Figure 1-234 illustrates the proper way to weld a container.



X2777 (1-234)
PROPER WAY TO WELD A CONTAINER
Courtesy of John Deere Ltd.

BACKFIRES AND FLASHBACKS

Backfires and flashbacks are a burning back of the preheat flames inside the equipment. In a backfire the burning goes into the mixing chamber. In the more serious flashback the burning goes into the hoses and regulators (Figure 1-235).


AREA SUSCEPTIBLE TO BACKFIRES & BURNBACKS
AREA SUSCEPTIBLE TO FLASHBACKS (Includes Regulators)
REGULATORS
NUT
NEEDLE VALVES
TIP
MIXER
HANDLE
HOSE

(1-235) BACKFIRES AND FLASHBACKS

When a backfire occurs, i.e., the flames disappear, followed almost immediately by a squealing noise from inside the blowpipe and by sparks coming out of the nozzle, the flames are burning in the chamber inside the blowpipe where the two gases oxygen and acetylene are mixed. You should quickly do the following:

1. Close the blowpipe preheat-oxygen valve.
2. Close the blowpipe acetylene valve.
3. Close the oxygen regulator.
4. Close the acetylene regulator.

If heavy smoke comes out of the nozzle, and if the blowpipe handle becomes hot, chances are a flashback has travelled beyond the mixing chamber of the blowpipe and is somewhere in the hose. You must act quickly! Shut off both gases at the cylinders. While closing the cylinder valves stand behind and away from the regulators. Before relighting the blowpipe, it is advisable to examine the various pieces of equipment for possible damage caused by the flashback.

Should a flashback travel back very rapidly and cause a fire to burst through the acetylene hose, close the acetylene cylinder valve immediately.

Repeated flashbacks or repeated backfires indicate that something is seriously wrong with the blowpipe or the manner of operating it. Shut down the entire system and try to find the trouble.

Causes Of Backfires

1. Too little gas flow — may be caused by low pressures or by failure to open needle valves enough to avoid the smoke range.
2. Obstruction of gas flow — may be caused by holding the torch too close to the work, by dipping the tip in the puddle, or by passing the rod end too close to the tip.
3. Loose or faulty seat connections between the tip and mixer — results in popping.
4. A dirty tip — metal particles collecting on the tip end, tend to retard gas flow and may cause backfires. Dirt in the tip passage causes obstruction and backfires.
5. A hot tip — may be caused by a series of backfires, or by working in deep grooves or blind holes. The heat in the tip preheats the gases, causing a rise in the speed of flame propagation and a rapid series of backfires result. To cool the tip close the needle valves, open the oxy-needle valve slightly and quench the torch in water. Blow out the water with oxygen, then relight the torch.

Causes Of Flashbacks

1. Grossly unequal pressures — cause the higher pressure gas to back up into the lower pressure line, and explode if the pressure and mixture are right.
2. Mildly unequal pressures along with an obstruction — if a tip blockage occurs, always close both needle valves immediately, then clean the tip.
3. Failure to purge each line individually before lighting the torch — a torch that has been sitting idle for awhile, may have an explosive mixture present in one line. The explosive mixture could be created by the torch being bumped or dropped, causing the needle valves to open slightly. Any obstruction of the tip would further increase the danger of this condition.
4. Faulty manipulation of valves — such as lighting a torch with both needle valves open, or otherwise failing to operate equipment in the recommended manner.

FUSION WELDING

In fusion welding two pieces of metal are brought together and the edges are melted with the oxyactylene flame. The molten metal will flow together with the metal of the welding rod until each edge is completely fused with the other. After the metal has cooled, there is a single continuous piece with no seam. In fusion welding, the base metal and the welding rod generally have essentially the same composition.

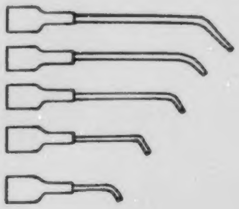
In all oxyacetylene welding, it is essential that the weld penetrates into the metal. With fairly light metal up to 1/8th inch, a distance equal to the thickness of the metal may be left between the pieces to be welded. This rule may also be used in welding standard pipe up to, but not over, one and one-half inches in diameter. Where the thickness of the metal is such that it would be difficult to secure full penetration if the edges were simply butted together, it is customary to bevel the edges before welding. Placing the two beveled pieces together forms a vee nearly through to the underside of the pieces. Thus the weld can penetrate right to the bottom of the joint.

Welding or filler rods used in fusion welding vary in size from 1/16th to 3/8ths inch in diameter. Filler rods are made from first grade steel with deoxidizers added and are governed under various specifications, e.g., ASTM, ASME, CSA.

Six main factors have to be considered when fusion welding mild steel:

1. Correct Size Tip

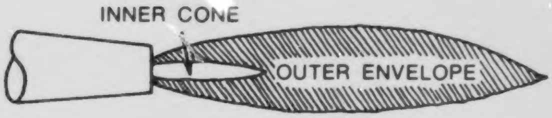
   Different tip sizes (Figure 1-236) are manufactured according to the different heat requirements of various thicknesses of steel. Unfortunately, the numbering systems for various tip sizes are not standardized and therefore the recommendations of different manufacturers must be followed. Every tip size has a maximum and a minimum flame setting. The preferred setting is one that delivers maximum heat without a harsh blowing effect.



(1-236)

2. Flame Setting

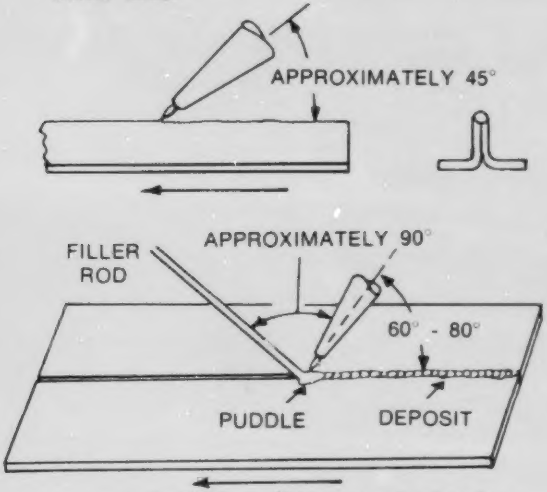
   The recommended flame setting (Figure 1-237) is neutral although some authorities suggest a very slight excess of acetylene.



(1-237)

3. Torch Angle

Depending on the requirements of heat and penetration, the torch may be held at an approximate angle of 45° for puddling or fusion without a filler rod (Figure 1-238). For the penetration necessary for full strength butt joints, the angle of the torch should be between 60° and 80°, and sometimes even 90° for flat position work. The steeper the angle the deeper the penetration. If one side is heavier, the angle should be such as to bring both sides to the melting temperature at the same time.

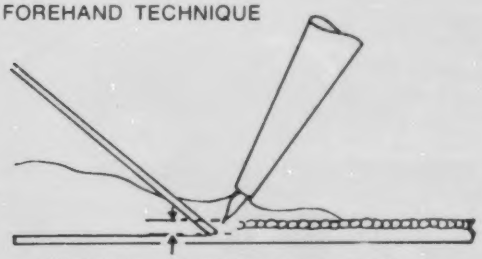

APPROXIMATELY 45°
FILLER ROD
APPROXIMATELY 90°
60° - 80°
PUDDLE
DEPOSIT

(1-238) DIRECTION OF TRAVEL

4. Distance Between Work and Flame

The hottest point of the flame is approximately 1/16th inch in front of the inner cone (Figure 1-239). If the cone is touched against the puddle the metal will carbonize and may become porous. On the other hand, if the cone is too far away, the effect of the protective outer envelope will be reduced and unnecessary oxidation (burning) might take place.

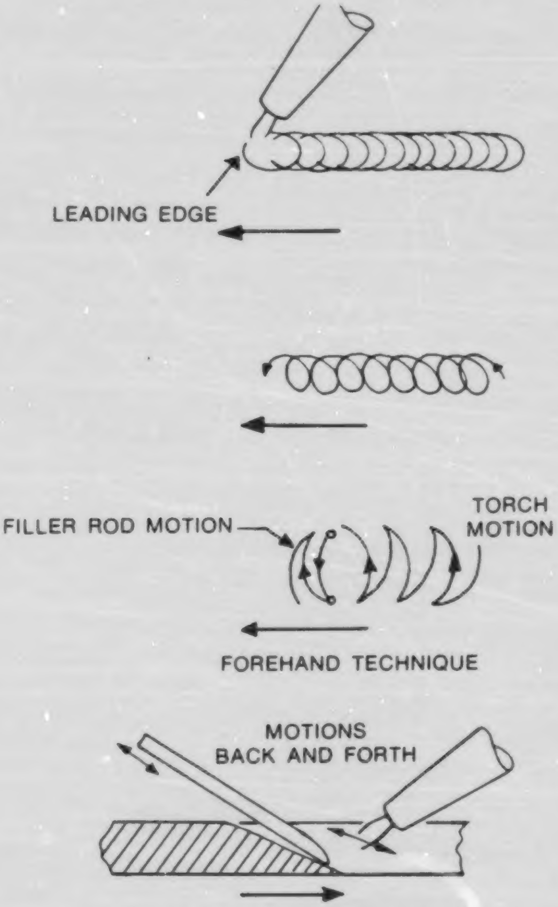
FOREHAND TECHNIQUE


DISTANCE OF CONE 1/16" - 1/8"

(1-239)

5. Speed Of Travel and Movements

The speed of travel depends on the heat requirement. The faster the torch is moved forward the less the heat will go into the steel. Generally speaking, for forehand welding the speed should be such that the inner cone will be at the leading edge of the puddle (Figure 1-240). For small, narrow beads the motion will have an oval pattern. In some cases where a wide weld bead is required, the torch may be moved from side to side in semi-circular motions, alternating with the rod. For backhand welding the torch is held at the front of the puddle and may be moved straight back and forth.


LEADING EDGE
FILLER ROD MOTION
TORCH MOTION
FOREHAND TECHNIQUE
MOTIONS BACK AND FORTH
BACKHAND TECHNIQUE

(1-240) WELDING TECHNIQUES

6. Operator Comfort and Position

   The operator must position himself comfortably, as this will enable him to produce the same high quality deposit in minimum time, even after many hours of work.

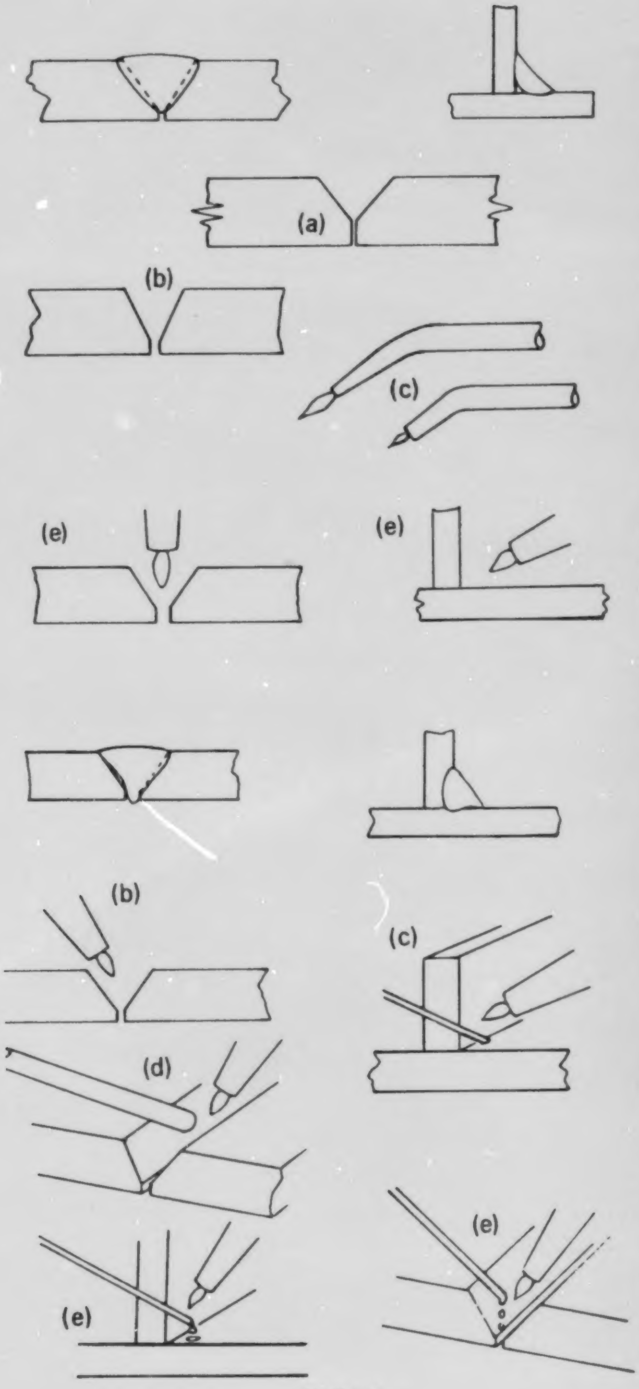
   Note: ALWAYS MELT THE PUDDLE FIRST, THEN ADD THE FILLER ROD.

Weldfaults

Weldfaults are illustrated in Figure 1-241.

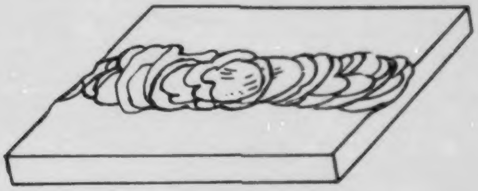
1. Lack of penetration:
   - (a) Land too heavy — root opening too small.
   - (b) "V" too narrow.
   - (c) Insufficient heat.
     Tip too small.
     Flame too small.
   - (d) Speed too fast.
     The faster the speed the less heat goes into the metal.
   - (e) Flame too far away from base metal.

2. Lack of fusion:
   - (a) Insufficient heat.
     Tip too small.
   - (b) Wrong angle of torch.
   - (c) Improper manipulation.
   - (d) Filler rod too large.
   - (e) Filler rod melted first.

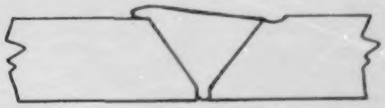


(1-241)

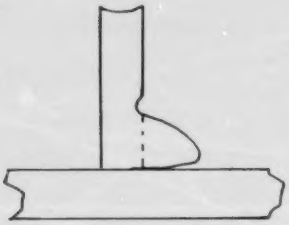
3. Poor appearance:
   - (a) Improper manipulation.
     Uneven distance of flame.
     Irregular torch and rod movement.
   - (b) Wrong flame setting
     Result of oxidizing or reducing flame.
   - (c) Insufficient heat.
   - (d) Dirty surface (oil, paint, etc.).

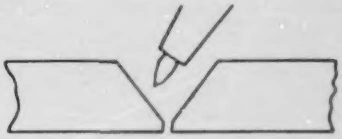


4. Crystallization (coarse grain structure).
   - (a) Overheating.

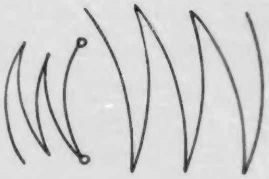


5. Undercut and overlap.
   - (a) Improper torch angle.
   - (b) Excessive heat and/or insufficient filler material.
   - (c) Puddle too large (does not solidify in time).
   - (d) Base metal too hot (puddle does not solidify in time).
   - (e) Incorrect torch and rod manipulation.



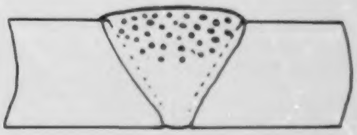


TORCH POSITION

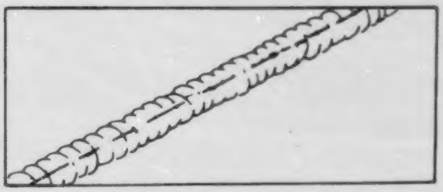


ROD POSITION

6. Porosity — great number of small gas pockets.
   - (a) Dirty surface (oil, paint, etc.) produces gases.
   - (b) Speed too fast. Gases cannot escape.
   - (c) Improper torch and rod manipulation, insufficient puddling.
   - (d) Touching inner cone to puddle.
   - (e) Improper flame setting, reducing or oxidizing flame.
   - (f) Excessive heat (boiling puddle).



7. Cracks in welds — surface, internal, longitudinal, transverse, crater and hair cracks.
   - (a) Joint too rigid.
   - (b) Faulty preparation, restrained weld.
   - (c) Weld stressed while in blue brittle range.
   - (d) Brittle base metal.
   - (e) Lack of preheat (if required).
   - (f) Secondary faults such as lack of penetration or fusion, porosity, hair cracks, etc.



(1-241)

Fusion Welding Of Cast Iron

Equipment needed:

- A tip at least as large as would be used on steel of the same size and thickness. Use a neutral flame.
- Cast iron rod. There are two types: "Fusewell #11" rod for plain castings, and "Fusewell Alloy #66" rod for higher grade alloy castings.
- Cast iron welding flux such as Hematox.

Welding Procedures

1. Prepare the break up to a 90° included angle. Tracers, small sections of the original break not removed in preparation are recommended to align the work. The tracers are later melted in.
2. Align and tack the work securely.
3. Support the work to prevent it from sagging while hot.
4. Totally preheat intricate castings to a full red temperature. Small simple shapes may be locally preheated red, but be sure to raise the temperature slowly, evenly and right across the weld area. Local preheating should be fairly wide and full red.
5. With a neutral flame, heat the rod end and dip it in the flux. Then heat the starting point until a water puddle is formed.
6. Add the rod by stirring the rod end in the bottom of the puddle to loosen the oxides. Let the oxides float to the surface. Oxides appear as white spots under the flame and if left will cause pinholes or blowholes. Often pinholes do not show up until the second pass is being made. In this case slowly lower the torch, cupping the molten puddle, and follow the pinhole down till the oxide appears. Flick it loose with the fluxed end of the rod, float it out, and slowly raise the torch allowing the cupped metal to flow inward. If the torch is raised quickly the metal rushes in and may trap gases causing further pinholes.
7. Work the puddle not only by stirring the rod, but also by circling the torch or by moving it from side to side, always watching for oxides and pinholes.
8. To avoid hard spots in cast iron:
   (a) Never add cold rod. Always heat the rod end before adding to the puddle.
   (b) Never allow the cone of the flame to touch the puddle.
   (c) Use only enough flux to keep the puddle clean and free flowing. Too much flux is just as bad as too little.
   (d) Avoid any rapid heating or cooling. Rapid cooling could occur from drafts or by just laying completed castings on cold plate.
9. Whenever possible try to make the weld in one pass. Working slightly up grade will assist in flowing heavier beads, but due to the high fluidity of the cast iron puddle, cast fusion welding is only done within the limits of the flat position. A helper handy with tongs can make the job easier. He should be able to anticipate the welder's needs.

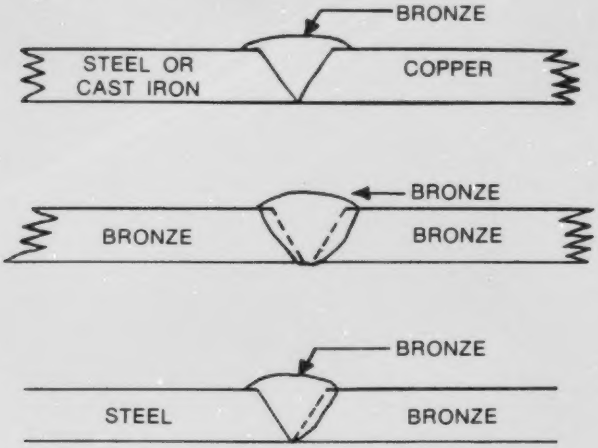
   Where more than one pass is required to fill the groove, it is necessary to even out the temperature right across the joint before starting each subsequent pass. Otherwise cracking of the root bead at the starting point will occur. The cracking may not be visible to the naked eye, but on a break test a dark colored oxidized section makes it obvious that a crack existed.
10. Keeping a temperature even, flow in weld ends and build them up if necessary. Build up should not exceed 10% of the thickness of the material.
11. Total post heat intricate castings to a full red heat. Once again take precautions against sagging. Cooling should be as slow as possible. It may be done in the oven, by tightly closing all openings to retard cooling, or slow cooling may be accomplished by burying the casting in slaked lime, dry ashes, or dry sand.

    Even simple shapes should be post heated and slow cooling is essential.
12. Where welds are to be machined, the application of monoclinic stick sulphur or bar laundry soap to the hot weld area immediately prior to burying will promote softness and good machinability.

BRAZE WELDING

In a true braze weld, the parent metal does not melt during the welding process. The joint is properly prepared and cleaned, then heated to a point where the grain structure opens up and tinning or amalgamation takes place (Figure 1-242). The tinning process is similar to soldering, with the exception that tobin or manganese bronze is used as a filler metal and of course the heat is considerably higher, usually in the dull red to medium red range.

On the other hand, where brass or bronze is joined using bronze rod, the joint is a true fusion weld. Both sides of the joint melt and flow in with the filler metal to form the weld (Figure 1-242).



(1-242) BRAZE WELDS

In some cases where brass or bronze is to be joined to iron, steel, or copper, only the brass or bronze side of the joint will melt. However, the joint is still referred to as a braze weld.

The metals to which bronze will adhere with satisfaction are: irons and steels (except those high in nickle or chromium such as the stainless group), copper, brass and bronze. Bronze will not take to non-ferrous materials such as nickle. Advantages of braze welding are:

1. Where less heat is used, there will be less warpage or distortion.
2. Braze welds tend to be much lower in residual stress.
3. Dissimilar metals may be easily joined using the brazing process.
4. Joints up to 60,000 psi tensile strength are possible.
5. Braze welds offer some joint flexibility or give.
6. The process is quick, clean and relatively cheap.

Braze welding is not used (rather, fusion welding is used):

1. When the work is subjected to intense heat, such as in the case of exhaust manifolds and lines on gasoline engines. Bronze is weak when too hot and will break down.
2. Where the work is subjected to alkali corrosion.
3. Where color match is essential.
4. Where rigid joints are required, since bronze has some give to it.
5. On second or third repairs when braze weld has originally been used. You can't trust old braze weld — a visual inspection will tell you nothing about the weld.

Braze Welding Procedures

Cast iron and malleable cast iron have by far the narrowest tinning range. Slightly too cold and tinning is shallow and weak. Slightly too hot and surface acids hinder or prevent tinning. The information here deals with braze welding cast iron, although the braze welding of other metals is similar, with the following exceptions:

1. The type of flame used and the type of flux used will change with the metal being brazed as the following table shows:

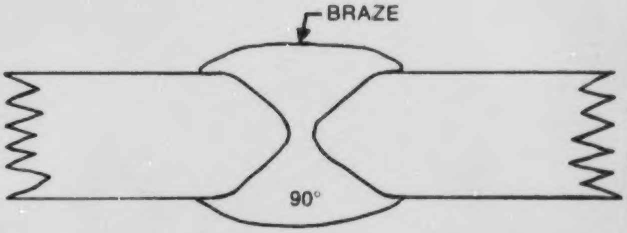
Metal To Be Joined	Flame Type	Flux Type*
Cast iron, malleable cast iron	Slightly carburizing	"Braze Weld" or coated rod
Wrought iron and steels	Slightly carburizing to neutral	"Copox" or coated rod
Galvanized iron and copper	Slightly oxidizing	"Copox" or coated rod
Fusion of brass or bronze	Slightly oxidizing	"Copox" or coated rod

***Note:** Generally, coated bronze rods have a universal type of flux. This is handy for most brazing jobs, but in heavy bronze build up work, it is often wise to go to bare bronze and add flux sparingly after the first layer has been deposited. Don't use too much flux as it can cause problems in machining the work. When bare rod is used, dip the heated end of the rod in the flux pot to pick up the needed amount of flux. When more is required, dip the rod again.

2. Only cast iron and malleable cast iron will require searing with an oxidizing flame to remove carbon smear. Where cast iron surfaces have been prepared by grinding, the free graphite in the cast iron smears across the ground surfaces, and retards tinning action. Since oxygen has an affinity for carbon, the oxidizing flame quickly removes this smear. Care should be taken in searing, not to oxidize the metal surfaces. At the first sign of any temper colors such as straw yellow, stop the searing.

Joint Preparation

Since the strength of a braze weld depends entirely on the amount of properly tinned joint surface, the use of wide Vee's is recommended. A 90° included angle should be considered a minimum (Figure 1-243). The shoulders of the joint should be cleaned back so bronze may flow over the shoulders. Weld ends should be cleaned to the full bead width, so they can be floated over with bronze. Double-V preparation is, of course, better than single-V, but if the latter must be used, round off the root of the joint and clean back the under surface so the bronze may flow through the root and spread on the underside (Figure 1-243).

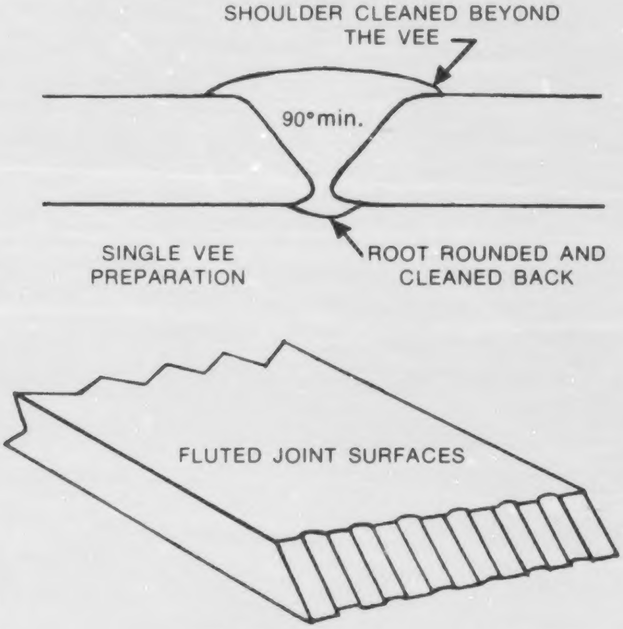


DOUBLE-V PREPARATION

(1-243)

When preparing a joint sharp corners and edges should be avoided as they tend to overheat and oxidize. Once oxidized, they will not tin properly and the joint will be weak.

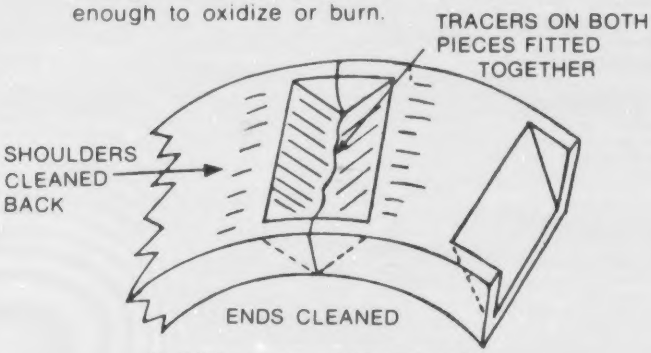
The use of fluted joints will further increase tinning surface, but again avoid sharp edges (Figure 1-244).


SHOULDER CLEANED BEYOND THE VEE
90° min.
SINGLE VEE PREPARATION
ROOT ROUNDED AND CLEANED BACK
FLUTED JOINT SURFACES

(1-244) JOINT PREPARATION

Braze Welding Cast Iron

1. Properly prepare the joint. The use of tracers is recommended to help in aligning the parts of odd shaped pieces. Since cast iron does not take a permanent bend before it breaks, the pieces may be fitted back together on the breaks and proper alignment is assured (Figure 1-245). Tracers should be small enough to tin through, but not small enough to oxidize or burn.



(1-245) JOINT PREPARATION

2. Sear joint surfaces with strongly oxidizing flame to remove carbon smear. Do not overheat the work so the ground surfaces are discolored. Sand blasted surfaces or chipped grooves, are best, but grinding is more common.
3. Align and tack the work securely.
4. Support the work adequately to prevent sagging. Intricate castings should be totally preheated to a grey color. Even simple shapes should receive a local slow even preheat right across the entire joint area.
5. Slightly carburize the flame (1⅛ times) to neutral. Hold it back from the work, and keep it moving to promote even heating. Bring the joint temperature at starting point to a red dull.
6. Put a drop of braze (with flux) on the work and watch the reaction.
   - (a) If the drop of bronze flows quickly, evenly, and smoothly, with little or no fuming, the temperature of the work is approximately right.
   - (b) If the work is too cold, the bronze drop sits like a ball, and refuses to flow. Add further heat around the drop of bronze till it spreads and flows evenly. Do not add heat on the bronze drop as it will burn quickly, giving off a puff of white zinc-oxide fumes, which normally would mean too much heat. In this case, however, it's the bronze drop that is too hot, and the work is still too cold. When good smooth even flow is established, the tinning temperature has been reached.
   - (c) If the work is too hot when the bronze is added, a puff of white fumes appears, often accompanied by blue flame in the puddle. The bronze flows very quickly and unevenly, leaving islands of oxides that refuse to tin. The oxides appear as white spots under the flame. Subsequent passes of weld metal will cover these spots but they still are not tinned and they seriously weaken the joint. Where overheating occurs, reclean the surfaces, removing the oxides.

7. When the tinning temperature is reached, add the rod almost continuously by circling or moving it from side to side. At the same time keep the torch moving to promote even heating and to prevent burning of local areas.

   If the work shows signs of becoming too hot:

   (a) Reduce the heat slightly.

   (b) Inline the torch more towards the rod to melt it faster. The weld will progress faster and lessen the heat put into the work.

   (c) Hold the torch slightly further away from the work to lower the temperature.

   If the work shows signs of being too cool, remove the rod for a short period of time or increase the heat.

8. Wherever possible try to make braze welds in one pass. Tinning, filling, and beading should progress simultaneously. Working up grade will assist in flowing heavy beads.

   If more than one pass is required to complete the weld, the first pass should seal the root and completely tin the joint surfaces, otherwise oxides will form on the untinned areas. Subsequent passes become bronze fusion welding and the flame should be changed to slightly oxidizing to both reduce fuming and the tendency of the bronze to become spongy.

9. In completing the weld, be sure to float over weld ends, thus eliminating notching.

10. Intricate castings should receive a total post heat to dull red. Even simple shapes benefit from post heat treatment. Allow the work to cool slowly.

QUESTIONS — WELDING

1. A recommended practice is to store full and empty oxygen and acetylene cylinders:
   (a) under cover in one common room
   (b) in the open, but separated
   (c) under cover, in separate rooms, with empty and full cylinders separated
   (d) Both (b) and (c) are correct

2. The identifying colors for oxygen and acetylene hoses are:
   (a) red, oxygen; green, acetylene
   (b) red, acetylene; green, oxygen
   (c) red, acetylene; blue, oxygen
   (d) blue, acetylene; red, oxygen

3. It is standard on oxygen and acetylene welding equipment to have:
   (a) right-hand threads on oxygen lines left-hand threads on acetylene lines
   (b) left-hand threads on oxygen lines right-hand threads on acetylene lines
   (c) right-hand threads on both lines only hose color is used for identification
   (d) left-hand threads on both lines only hose color is used for identification

4. The regulator is a device connected to the cylinder that __________ high pressure in the cylinder and maintains a __________ __________ pressure.

5. Pressure in a full oxygen cylinder is 2200 psi at 21 C. As the temperature increases:
   (a) the weight and pressure increases
   (b) the weight stays the same and the pressure increases
   (c) the weight increases but the pressure decreases
   (d) no change takes place in either the weight or pressure

6. What is the maximum safe operating pressure when using acetylene gas for welding or cutting?
   (a) 45 psi
   (b) 25 psi
   (c) 15 psi
   (d) 5 psi

7. In what position should acetylene cylinders be stored?

8. Acetylene is sold by:
   (a) gallons
   (b) weight
   (c) pressure
   (d) liters

9. If oil or grease contacts pure oxygen, what is likely to occur?

10. Tips of welding or cutting torches are cleaned with:
    (a) special brushes
    (b) hot soapy water, then blown dry
    (c) solvent or any petroleum type cleaner
    (d) tip cleaners or tip drills

11. True or False? Torches can be safely relit from hot metal.

12. Before installing regulators on cylinders, a good practice is to:
    (a) oil the threads
    (b) crack the cylinder valves to blow out dirt
    (c) Both of (a) and (b) are recommended

13. Once gauges are installed, open the cylinder valves __________, first the acetylene, normally __________ turn, then oxygen __________.

14. Briefly explain how to check for leaks once the torch is set up.

15. For fusion welding, what type of flame is recommended?
    (a) neutral flame
    (b) oxidizing flame
    (c) reducing flame
    (d) fusion flame

16. When shutting down welding equipment which cylinder is turned off first?

17. List three signs that indicate a flashback has occurred.

18. List the four steps in order, that must be taken if a flashback occurs.

19. Fusion welding is a process whereby two pieces of metal are brought together and the edges are ________ with the oxyacetylene flame.

20. As opposed to a fusion weld, in a true braze weld the parent metal does not ________ during the welding process. Only the rod does.

21. List three causes of backfire.

22. Briefly explain how flame cutting of steel is accomplished.

23. For your safety and protection list the necessary protective equipment that should be worn when using oxyacetylene welding or cutting equipment.

24. After fusion welding cast iron the work should be:

    (a) coooled quickly

    (b) cooled very slowly

    (c) cooled in the air

25. When fusion welding two pieces of metal it is best to ________ the edges of the metal on the weld line.

26. When preparing a joint for a braze weld, V-joints are recommended with included angles of ________ degrees.

27. If the work is too hot when bronze welding, ________ spots will appear that won't tin properly.

28. True or False? Flame cutting requires preheating.

29. The tip selected for a cutting job will depend on the ________ of the metal to be cut.

ANSWERS — HAND TOOLS, SHOP SAFETY, SERVICE LITERATURE

1. (c) make, model, and serial number
2. False
3. (b) 4
4. True
5. eyes, back, hands, head, feet and ears
6. B
7. (d) protect machined surfaces
8. False
9. internal or external
10. (b) reamed
11. False
12. (b) 8° to 12°
13. (d) making a chisel cut on the side to which the drill should be drawn
14. (c) margin
15. (c) over the margin
16. (a) No. 1 to 80
17. (b) 118°
18. (a) a tap cuts threads in a hole, and a die cuts threads on a rod
19. (b) taper, plug, and bottoming
20. (b) after a taper tap
21. (b)
22. (c) drill a pilot hole
23. Do not turn it backwards.
24. (c) planetary gears
25. cold chisel, cape chisel, round nose chisel and diamond point chisel
26. (c) file cuts
27. center, starting and pin
28. common, phillips, clutch head and offset
29. rubber, brass, plastic and rawhide
30. combination, needle nose, vise grip and diagonal
31. (c) rough or coarse-cut file
32. (b) double cut
33. Lightly drawing the file crosswise over a surface to finish it.
34. two
35. (b) on the forward stroke only
36. number of teeth
37. (a) the handle of the vise only
38. To protect finished surfaces.
39. (c) away from the handle
40. (c) 12 notches
41. (c) width of the bolt head across the flats
42. Pull on the permanent side of the wrench, not on the adjustable side.
43. (b) 1/16th inch
44. (c) notches
45. The offset allows more swing when the wrench is flopped.
46. The tubing wrench holds like a box wrench yet is open on the end like and open-end wrench.
47.
    1. ratchet
    2. flex handle
    3. speed handle
    4. universal joint
    5. extension
48. (c) safeguard on over stressing parts
49. (d) 5 feet-pounds
50. reach and spread . . . .
51. (d) 7 to 10
52. (b) the shortest legs possible
53. . . . tinned . . . .
54. To clean the metal of oxides and help the solder fuse the metals.
55. (a) resin flux
56. (b) heli-coil

ANSWERS — AIR, ELECTRIC AND HYDRAULIC POWER TOOLS

1. (b) 1/16"
2. True
3. . . . cool.
4. The drill press has greater accuracy.
5. . . . overtighten . . . .
6. Know how they come apart.
7. Puller, pump and reservoir, and adapter.
8. The 3/8th inch is faster than 1/2 inch, but has less torque.
9. False

ANSWERS — MEASURING TOOLS

1. (b) steel rule
2. (a) 3.890 (b) 5.370 (c) 3.375
3. 1. anvil
   2. frame
   3. spindle
   4. lock
   5. ratchet
   6. thimble
   7. barrel
4. (b) between three and four inches
5. (c) 3.187
6. (a) 3.812
7. (a) .812 (b) .770 (c) .665 (d) .875
8. (a) 2.80 (b) 5.04 (c) 10.5 (d) 10.33
9. (a) .187 (b) .246 (c) .340 (d) .125
10. (a) 22.65 (b) 19.29 (c) 15.00 (d) 15.34
11. (b) telescoping gauge and outside micrometer
12. (b) diameter of a hole
13. True
14. (c) go-no-go gauge
15. (d) cut off to remove damaged portion

ANSWERS — FASTENERS

1. (a) slash marks
2. The distance from under the head to the end of the threaded part.
3. (c) diameter of the bolt or screw
4. (b) number of threads per inch
5. (c) the grade
6. Three slashes indicates grade 5.
7. (c) the number of threads per inch
8. (c) nuts
9. (c) screws
10. (d) a cotter pin
11. False
12. (c) across the flats on the head

hex head bolt	3
plow bolt	9
hex socket head	5
12-point head bolt	2
hex nut	6
castle nut	8
lock washer	10
lock nut	4
flat washer	1
slotted nut	7

14. striking wrench, cutting torch, nut splitter, hacksaw and penetrating oil
15. A woodruff key sits deeper in a shaft thereby giving more support.
16. False. Tighten it.
17. False. Bend it against one flat only.

ANSWERS — HOSES, PIPES, TUBES, FITTINGS AND ADAPTERS

1. (d) 1/16th of an inch
2. (a) decreases
3. (c) the length up to the notch on the fitting socket
4. (d) all of the above
5. (b) have different seating angles and thread pitches
6. The galvanizing may flake off and contaminate the system.
7. Because it becomes brittle when subjected to heat and will break at the flared joints.
8. (b) OD alone
9. (c) ID and wall thickness
10.

iron pipe fitting	2
solderless compression fitting	1
inverted flared fitting	5
double compression fitting	4
SAE flared fitting	3

ANSWERS — LIFTING AND BLOCKING

1. Cranes, forklifts and jacks.
2. The lifting capacity of the equipment must be clearly marked on it.
3. Block the vehicle with approved blocking or stands.
4. If only one link is weak a chain can break, whereas many strands of wire must break before the wire rope would break.
5. Chains cannot kink and will more easily take the shape of the object being lifted.
6. Increase.
7. . . . 45 degrees.
8. False
9. (c) the diameter of the material in the bow
10. (d) a pipe sleeve and washer are used to support it and prevent it from bending
11. (b) one and one-half times the bolt diameter
12. (d) both (b) and (c) are correct
13. . . . stands and square wood blocks.
14. . . . bridging.
15. In the service manual.
16. (c) discard the chain
17. — cracks
    — nicks, gouges
    — stretched links
    — bent, twisted links
    — worn links
18. Protect the wire rope with blocking or pads.
19. False
20. . . . shackle.

ANSWERS — WELDING

1. (c) under cover, in separate rooms, with empty and full cylinders separated
2. (b) red, acetylene; green, oxygen
3. (a) right-hand threads on oxygen lines left-hand threads on acetylene lines
4. . . . reduces . . . constant working pressure.
5. (b) the weight stays the same and the pressure increases.
6. (c) 15 psi
7. Upright.
8. (b) weight
9. An explosion.
10. (d) tip cleaners or tip drills
11. False
12. (b) crack the cylinder valves to blow out dirt.
13. . . . slowly, . . . half a turn . . . all the way.
14. Turn on the cylinder valves, set the working pressures, turn the cylinder valves off. If there's a pressure drop on the high pressure gauge, there's a leak.
15. (a) neutral flame
16. acetylene
17.
    - — squealing or hissing noise from inside the blowpipe
    - — sparks coming out of the nozzle
    - — heavy black smoke coming out of the nozzle
18.
    - — close the blowpipe oxygen valve
    - — close the blowpipe acetylene valve
    - — close the oxygen regulator
    - — close the acetylene regulator
19. . . . melted . . . .
20. . . . melt . . . .
21.
    - — faulty seat conditions between tip and mixer
    - — too little gas flow
    - — tip too hot from being too close to the work
    - — dirty tip
22. A jet of pure oxygen from the cutting torch is directed against the heated steel causing rapid oxidation and combustion of the metal.
23.
    - — goggles
    - — leather gloves
    - — leather apron, if available
24. (b) cooled very slowly
25. . . . bevel . . . .
26. . . . 90 degrees.
27. . . . white oxide . . . .
28. True
29. . . . thickness . . . .

TASKS — SHOP EQUIPMENT AND PRACTICES

HANDTOOLS, POWER TOOLS AND BENCH WORK

1. Gain experience using the hand tools and power tools discussed in this block.
2. Steam clean an engine or transmission so that it is clean enough to work on, starting, using and stopping the steam machine without assistance.
3. Clamp in a vise a piece of mild steel, e.g., ¼" × 2", and cut a 3" piece with a hacksaw.
4. Clamp the 3" piece of steel with the cut end up, and square the end with a file.
5. Select the correct size drill bit for ¼" NF thread, and using a drill press, drill a hole through the flat of the metal.
6. Using a taper and then a plug tap, thread the hole to ¼" NF.
7. Using a vise and hacksaw, cut a piece of ¼" round stock 6" long.
8. Clamp the 6" piece of round stock vertically in a vise, taper its end with a file, and thread it with a ¼" NF die for 2". When complete, the rod should thread in the tapped hole (made in Task 6) with ease.
9. Locate a broken stud which has broken at or below the surface. Using the correct drill and stud-removing equipment, remove it without damaging the threads of the tapped hole.
10. Locate a worn hole in a casting (preferably aluminum) and using a thread restorer kit install a thread restorer the same size as the original.
11. Clean and flux two pieces of 20 gauge metal, then with a torch and solder make a lapped joint.
12. With a soldering iron and rosin core solder, clean and solder two pieces of 12 gauge wire to form a good connection.
13. Using a small hammer, snips, and hole punches, make:
    - a paper gasket (e.g., water outlet gasket)
    - a cork gasket (e.g., oil inspection cover gasket)
    - an asbestos gasket (e.g., an exhaust flange gasket)

MEASURING TOOLS

Using the indicated precision measuring instrument, take the following measurements:

1. With an outside micrometer, measure the throw on a crankshaft for taper and out of round to within .001" (.025 mm) of manufacturer's specifications.
2. Using an inside micrometer, measure the bores on an engine for taper and out of round to within .001" (.025 mm) of manufacturer's specifications.
3. With a depth micrometer, measure the counter bore depth on an engine block to within .001" (.025 mm) of manufacturer's specifications.

HOSES, TUBES, PIPES, FITTINGS AND ADAPTERS

Hose and Fittings

1. Matching the correct size and type of hose with replaceable fittings, make up a low, a medium, and a high pressure hose, using the correct procedures and hose make-up tool kit or hand tools.

Tubing and Fittings

1. Using a tubing cutter, cut a 10" piece of 5/16" copper tubing from a roll. Ream the ends in preparation for flaring.
2. Using a flaring tool kit, flare one end of the tube with a single flare. Then put two 5/16" SAE flare tube nuts onto the tube from the end not yet flared. Make sure the nuts face the right way. Now double flare the other end of the tube. The flares must be straight and square with the tubing, and be large enough to support the fittings yet not so large that they interfere with the nut or won't fit inside the nut.
3. When the flaring is complete bend the tubing.

Pipe and Fittings

1. Clamp a piece of 1/2" pipe (black or galvanized) in a pipe vise, and using a pipe cutter, cut an 18 inch piece.
2. Clamp the 18 inch piece of pipe in a pipe vise and ream both ends in preparation for threading.
3. Using half inch pipe dies and cutting oil, cut threads on both ends approximately one inch long. The threads are acceptable if none are torn or damaged and if you can turn a pipe fitting onto the threads three turns by hand.

LIFTING AND BLOCKING

Do all the following lifting tasks for which the equipment is available to you:

1. Using an overhead crane with the correct slings or chains, lift and securely block a truck or wheel loader at a height suitable to allow working on the wheel assembly. Lower the vehicle safely.
2. Using an overhead chain block hoist with the correct slings or chains, lift and securely block a truck or wheel loader at a height suitable to allow working on the wheel assembly. Lower the vehicle safely.
3. Using an appropriate size hydraulic jack, lift a crawler tractor in the shop or in the field and securely block it with wood blocking or metal stands at a height suitable to allow working on the undercarriage. Lower the tractor safely.
4. Operating a forklift, lift several objects such as a loaded pallet board, an engine assembly, a track frame. Move the object to its desired location and lower it safely. Park the forklift and lower the forks.

WELDING

The following tasks are to be preformed under the supervision of a qualified mechanic who has a working knowledge of oxyacetylene cutting and welding equipment.

1. Using the cutting head attachment for oxyacetylene equipment, make a clean, straight cut on the metals listed below, selecting the correct size tip for the job and correctly assembling and adjusting the tip:
   - — plate or flat bar up to one-half inch material
   - — angle iron
   - — channel iron
   - — H-beam iron
   - — rusted iron

   Also, use oxyacetylene cutting equipment to:
   - — split welded plates and brackets
   - — cut off rivets, bolt heads and nuts
   - — pierce bolt holes
2. Get experience using a large rosebud heating tip on jobs that require heating to remove components, e.g., removing press-fit parts.
3. Make a fusion weld to join two pieces of exhaust tubing, using the right size welding tip. The joint should be gas tight.
4. Make a brazed lapped joint on two pieces of gauge metal using the right size welding tip.

BLOCK

2

Starting, Moving and Stopping Equipment

STARTING, MOVING AND STOPPING EQUIPMENT 2:1

Starting, moving and stopping equipment is part of a heavy duty mechanic's job. The mechanic must know:

1. What to check prior to starting a machine (pre-start checks).
2. How to start a machine under varying climatic conditions.
3. How to safely move a machine.
4. How to shut down a machine for both overnight and extended periods.

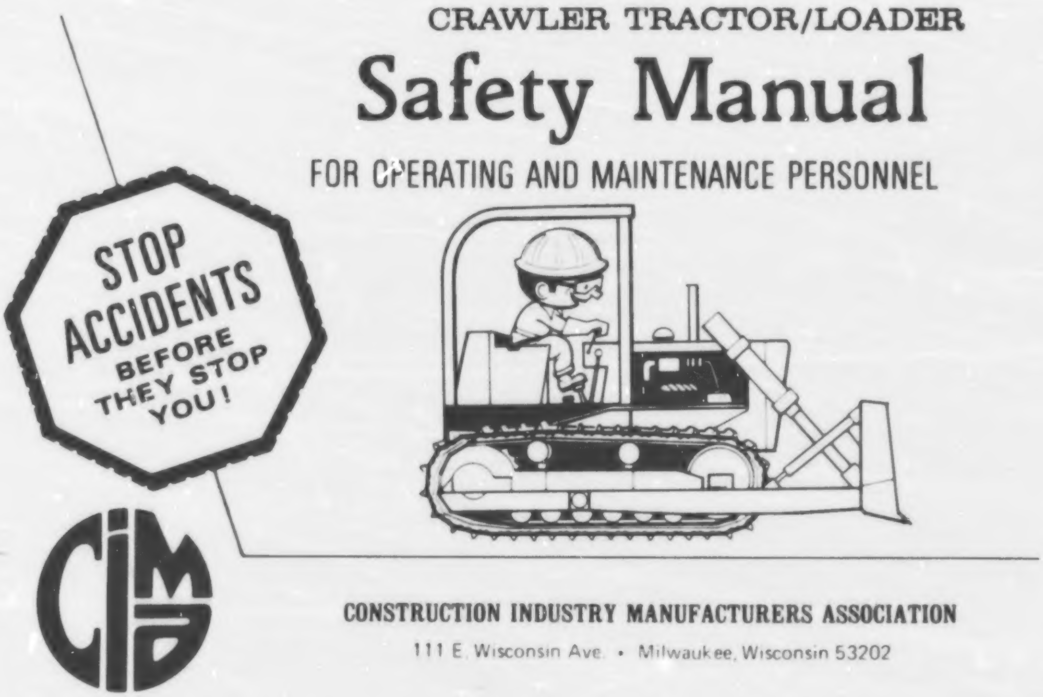
One of the best sources of information on the operation of equipment is manufacturer's Operating Manuals. Some manufacturers have information for the operator and the maintenance man in one manual, where as others supply two manuals: an Operator's Manual and a Lubrication and Maintenance Manual.

There are also some good publications such as the Construction Industry Manufacturer's Association (CIMA) Manuals that deal with general procedures and safe practices to follow when moving or working on heavy equipment. Some examples of CIMA Manuals are:

Motor Grader — Safety Manual for Operating and Maintenance Personnel

Crawler Tractor/Loader — Safety Manual for Operating and Maintenance Personnel (Figure 2-1)

Hydraulic Excavator — Users Safety Manual



CRAWLER TRACTOR/LOADER

Safety Manual

FOR OPERATING AND MAINTENANCE PERSONNEL

STOP ACCIDENTS BEFORE THEY STOP YOU!

CONSTRUCTION INDUSTRY MANUFACTURERS ASSOCIATION

111 E. Wisconsin Ave. • Milwaukee, Wisconsin 53202

(2-1)

Courtesy of Construction Industry Manufacturers Association (CIMA)

Obviously it is not possible to be familiar with the operation of all heavy duty machines. However, you should acquire and read Operator's manuals for each piece of equipment that you service in your shop. Find out all you can about the machines you work on; the knowledge will make your job easier, and will make you a better mechanic.

Initial experience moving a machine should be done under the guidance of a qualified person.

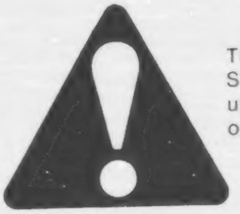
PRE-START CHECKS

A pre-start check is a systematic series of checks on engine driven equipment prior to starting. The checks are intended to see that the machine is in good, safe running condition before it goes out to do its day's work. Besides protecting people from injury and the machine from negligent damage, pre-start checks are part of a good maintenance program. Any minor problems on the machine will be noticed and can be repaired before they become major ones.

Generally, pre-start checks are the responsibility of the operator. However, the policy of some companies is to have mechanics do pre-start checks to prepare the machine for its daily shift. In any case, you should be aware of pre-start procedures since they are part of machine maintenance. In addition, you will have to move machines, and even though you wouldn't do as thorough a pre-start check to move a machine as you would to prepare one for a shift, you will still make some of the checks.

Before beginning pre-start checks put the machine in the service position:

- Put all the attachments on the ground and put all hydraulic controls in neutral.
- Apply the parking brake and the transmission neutral safety lock.
- Turn the ignition key to the off position, (and pull the engine stop handle if the machine is equipped with one).
- Remove the ignition key from the ignition switch and open the master switch.
- Fasten a red warning flag to the canopy upright or attach a DO NOT START TAG to the steering wheel.
- Fasten the safety bar on machines with articulated steering.
- Stop the wheels from rolling by putting blocks against the tires (if applicable).

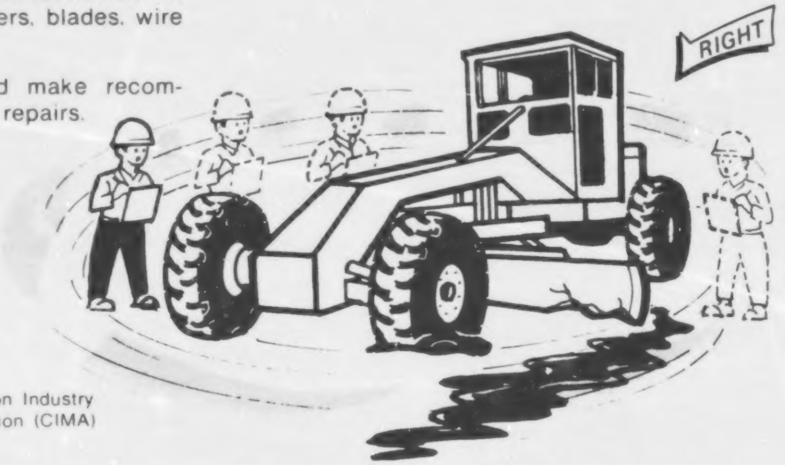


This is the SAFETY ALERT SYMBOL. You will see it used throughout service and operator's manuals.

To do a Pre-Start Inspection, also called a Daily Walk Around Inspection, refer to the manual for the machine you are working on. Although pre-start checks vary from machine to machine, there are checks common to most machines. These include:

1. Record the service hours or miles.
2. Locate, check and top up, if necessary, all fluid levels including coolant, fuel, battery electrolyte, lube oil. Keep records of fluid additions.
3. It is best to fill the fuel tank at the end of a shift to reduce condensation. Drain a small amount of fuel from the tank at the start of a shift to remove any water and sediment. Also check the water trap.
4. Check the condition and tension of drive belts.
5. Drain air reservoirs (if so equipped), although this is also best done at the end of a shift.
6. Do a walk around inspection to review the machine's general condition (Figure 2-2).
    - visually inspect the undercarriage, frame and suspension for loose bolts and missing parts.
    - check to see that mountings of hang-on components are tight.
    - check for fluid leaks: lube oil, hydraulic oil, coolant, fuel.
    - examine pipes and hoses for damage or leaks and gasket joints for leaks.
    - check tire pressure and wheel studs.

- check the condition of working attachments: buckets and teeth, booms, arms, hydraulic cylinders, blades, wire ropes.
- do minor repairs and make recommendations for major repairs.



(2-2)

Courtesy of Construction Industry Manufacturers Association (CIMA)

Some companies will make up Pre-start Check Lists for their own machines. An example is shown below

Date: ______________________________

Model ________________ Serial ______________________ Hour Meter ______________

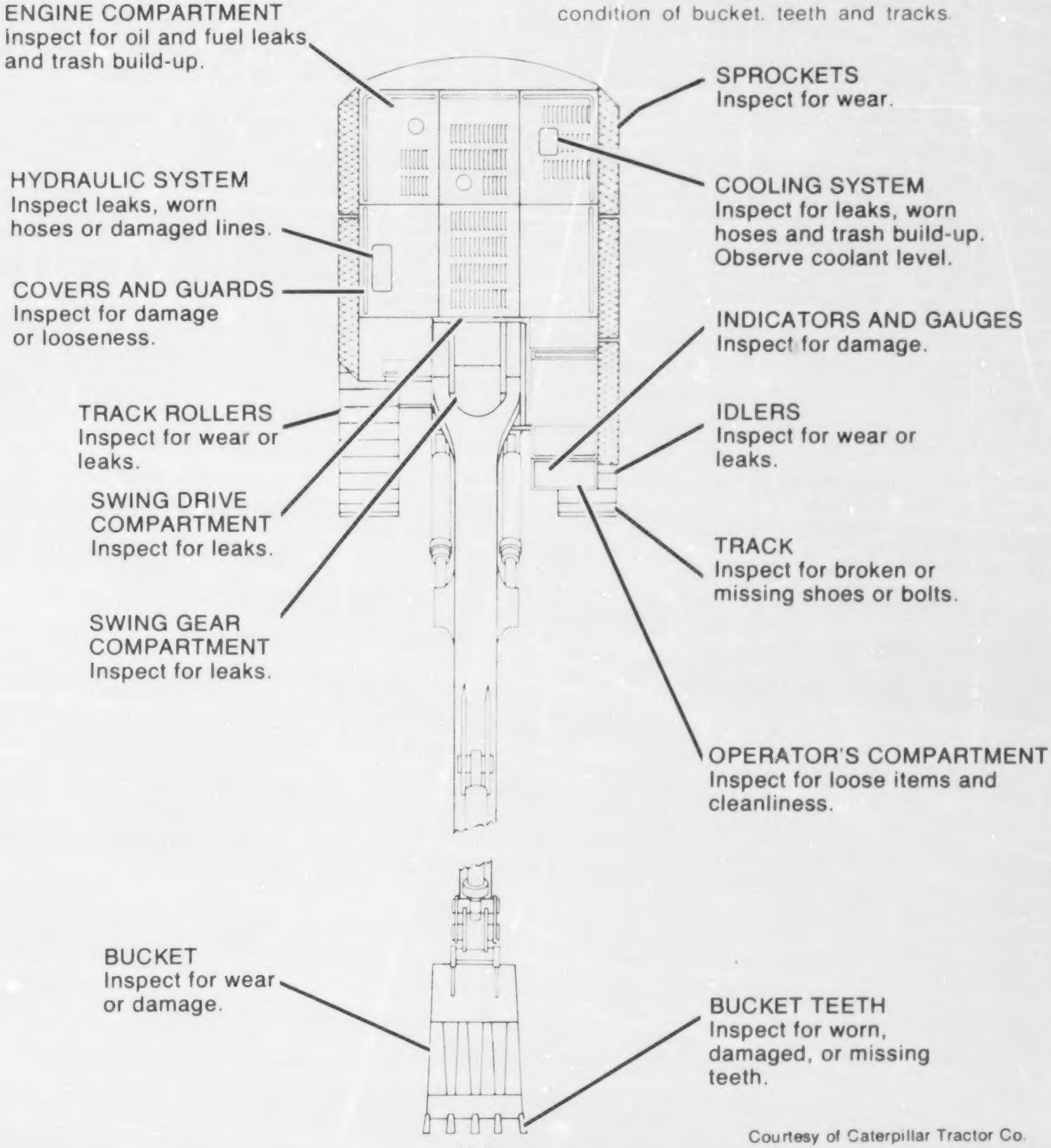
1. Check fuel	OK ________	Added ________
2. Check fan belts	OK ________	Replace ________
3. Check hydraulic pump belts	OK ________	Replace ________
4. Check water pump belts	OK ________	Replace ________
5. Check hydraulic hoses for leaks or chafing	OK ________	Replace ________
6. Check hydraulic fittings and valves for leaks	OK ________	Repair ________
7. Service air cleaner	OK ________	Replace ________
8. Service compressor air cleaner	OK ________	Replace ________
9. Check air system (Brakes)	OK ________	Repair ________
10. Drain air tanks	OK ________	
11. Check wheel studs — visually	OK ________	Replace ________
12. Check for loose nuts and bolts	OK ________	Loose ________
13. Check all welds	OK ________	Repair ________
14. Check electrical system	OK ________	Repair ________
15. Check operating controls	OK ________	Repair ________

Following are two examples of manufacturer's Pre-start or Walk Around Checks. The first is for a hydraulic excavator, and the other is for an off-highway dump truck. For further examples, check operator's manuals at your shop.

WALK AROUND INSPECTION

HYDRAULIC EXCAVATOR
(Caterpillar)

For maintenance and operator personnel safety, and maximum service life of the machine, make a thorough walk around inspection when doing lubrication and maintenance work. Inspect under and around machine for such items as loose or missing bolts, trash build-up, oil, fuel or coolant leaks, condition of bucket, teeth and tracks.


ENGINE COMPARTMENT
Inspect for oil and fuel leaks and trash build-up.
SPROCKETS
Inspect for wear.
HYDRAULIC SYSTEM
Inspect leaks, worn hoses or damaged lines.
COOLING SYSTEM
Inspect for leaks, worn hoses and trash build-up. Observe coolant level.
COVERS AND GUARDS
Inspect for damage or looseness.
INDICATORS AND GAUGES
Inspect for damage.
TRACK ROLLERS
Inspect for wear or leaks.
IDLERS
Inspect for wear or leaks.
SWING DRIVE COMPARTMENT
Inspect for leaks.
TRACK
Inspect for broken or missing shoes or bolts.
SWING GEAR COMPARTMENT
Inspect for leaks.
OPERATOR'S COMPARTMENT
Inspect for loose items and cleanliness.
BUCKET
Inspect for wear or damage.
BUCKET TEETH
Inspect for worn, damaged, or missing teeth.

Courtesy of Caterpillar Tractor Co.

(2-3)

Ten hour service procedures for the excavator are given below.

ITEM	SERVICE
EVERY 10 SERVICE HOURS OR DAILY	
① Radiator	Observe coolant level
② Air Cleaner Precleaner	Inspect—clean
③ Engine Crankcase	Inspect oil level
④ Fuel Tank	Drain moisture and sediment
⑤ Warning Systems	Test

OFF-HIGHWAY TRUCK
(Wabco)

Haulpak
WABCO
Haulpak

BODY
FENDERS
NOT SHOWN

Courtesy of Wabco Construction and Mining Equipment

(2-4)

10 HOURS SERVICE CHECKS

1. **Shutters** — Check for proper operation of shutter control.
2. **Radiator** — Check level of coolant. Capacity — 120 gallons.
3. **Fan** — Check for proper operation of fan and condition of fan belt.
4. **Wheels** — Check wheel mounting bolts for proper torque — 270±25 ft. lbs. torque.
5. **Tires** — Check for proper inflation pressures. (36:00-51. 42 ply. Front and Rear 55 psi: 33:00-51. 50 ply optional. Front and Rear 70 psi.)
6. **Fuel Tank** — Drain condensation from fuel tank at drain cock near bottom of tank. Capacity — 500 gallons.
7. **Brake Fluid Reservoirs** — Check level. Fill with SAE-J1703 hydraulic brake fluid. Capacity 2.5 pts. Sub-zero temperatures use SAE-J1702B.

8. **Air Starter Lubricators** — Fill to oil level. Type Oil SAE-10W.
9. **Turbo-Chargers** — Check for leaks, vibration or unusual noise.
10. **Crankcase** — Check oil level. Capacity with filters 40 gal.; without filters 37 gal.
11. **Fuel Filter** — Drain condensation from filter.
12. **Fuel Strainer** — Drain condensation from filter.
13. **Air Reservoirs** — Drain condensation from all reservoirs.
14. **Air Cleaner** — Check service indicators on dash panel. Service filters if indicator shows red when engine is shut down.

STARTING AND MOVING EQUIPMENT

Once pre-start checks have been made, the engine can be started. The points below are common to starting and stopping all heavy duty vehicles and are discussed in order in the rest of this block.

- Emergency shut down procedures.
- Starting procedures to include the safe use of cold starting devices.
- After start checks, e.g., checking gauge readings and warning devices and testing brakes.
- Safely moving the machine and safely operating the working attachments.
- Stopping and Safe parking.
- Procedures for extended shut-down or storage.
- Safe practices when working on or around machines with articulated steering.

EMERGENCY SHUT DOWN PROCEDURES

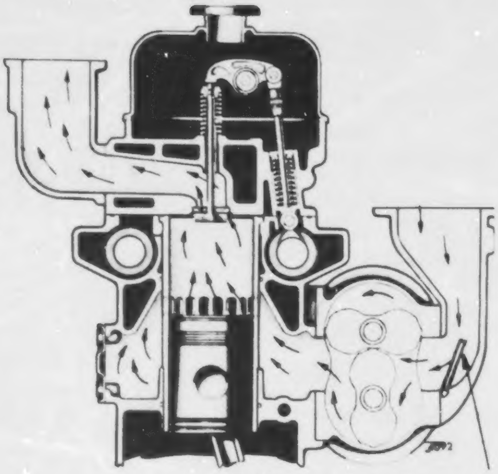
Before you start a machine, know how to stop it. A gasoline engine can be stopped by simply turning off the ignition switch. Since the engine is fired by spark ignition and the ignition switch controls current flow that creates the spark, turning the switch off stops the engine.

Stopping a diesel engine can be more difficult. A diesel fires its fuel by the heat of compression (see Block 7, Engines). Once the engine is cranked and fuel is supplied to the combustion chamber (assuming temperature conditions are right), the engine will start. The only way the engine can be stopped is (1) by shutting off the fuel (2) by cutting off the air or (3) by de-compressing the cylinders (on some engines).

The speed of a diesel engine is controlled strictly by the amount of fuel delivered to it. All diesel engines have a governor that senses engine RPM's and controls, through linkages, the amount of fuel delivered to the cylinders thus preventing the engine from over speeding. The governor limits the maximum RPM's to an amount safe for the engine. The throttle position controls the RPM's within the governor setting.

For normal engine shut down, either the throttle is moved to the No-Fuel position or the fuel is shut off by an electric solenoid control valve. In either case there should be no problem in stopping the engine. However, should a fuel system malfunction during start up or while the engine is running, excessive fuel feeding could cause an uncontrolled speed increase in the engine. Such an RPM increase can happen in seconds, and if emergency procedures are not taken immediately, the engine will over speed to destruction. If the malfunction is in the governor, it may not be possible to cut off the fuel supply. The other alternatives left are to cut off the air supply or to decompress the cylinders.

Some engines, for example Detroit Diesel, have an emergency shut down device that cuts off the air supply to the engine. A flapper valve (Figure 2-5) is located in the air inlet of the engine and is operated by a cable attached to the control panel. Pulling the control releases a catch, allowing spring pressure to close the flap and shut off the air supply. If the engine has reached a runaway speed, the flap may not stop the engine but will slow it to a point where you can safely get near and disconnect the fuel line. Note that the flapper valve is to be used for emergencies only and not for normal shut down; regular use of it can damage seals within the scavenge blower.



(2-5) FLAPPER VALVE

Courtesy of Detroit Diesel General Motors Corporation

The other method of stopping the engine is by decompressing the cylinders. Some engines are equipped with a decompression mechanism which lifts either the intake or the exhaust valves from their seats. The mechanism is an engine starting aid, but in an emergency it can be used to stop the engine. Service manuals will recommend that decompression mechanisms not be used to stop an engine, especially not at high RPM's but in the event of a runaway engine anything is better than letting the engine destroy itself. On a regular basis, though, do not use the compression release to stop the engine because this could result in the push rods being pulled from their sockets and also cause extensive wear on the balls and sockets.

Precautions must be taken when starting a diesel engine after it has been shut down for a period of time, or after it has been overhauled, because there is a danger of these engines running away. The best precaution is to get a piece of smooth plywood larger than the intake manifold opening. Leave any piping off and have the plywood ready to cover the manifold opening to cut the air supply in case the engine races. Possibly it won't be needed, but in the event that it is you'll be prepared. Don't take chances.

Diesel engine sentinel systems should be mentioned here. Although they are not, technically speaking, emergency shutdown devices, they are related. Sentinel systems are signal devices which automatically (through an electric solenoid control) cut off the fuel supply or move the fuel control to the no-fuel position if:

1. the engine overheats
2. the oil pressure becomes low
3. the engine overspeeds (Only on some sentinel systems. One manufacturer's signal device actuates when the engine reaches a speed that is 18% greater than full load speed).

Remember, a runaway diesel engine is a dangerous and frightening thing to be near. Know how to stop one.

STARTING PROCEDURES, COLD STARTING AIDS, AND STOPPING PROCEDURES

SAFETY POINTS ON STARTING

Your safety and the safety of those around you depends upon your using care and judgment in the operation of equipment. Know the positions and the functions of all controls. All equipment has limitations. Understand the speed, braking, steering, stability and load characteristics of the vehicle before starting to operate it.

Before moving a machine, or its attachments, be sure people in the area are clear of the machine. Walk completely around the machine before mounting it. Sound the horn.

If the engine is to be started indoors, ensure proper ventilation to remove deadly exhaust gases.

Never leave the machine unattended with the engine running.

STARTING PROCEDURES, INCLUDING SAFE USE OF COLD STARTING AIDS

Manufacturers have specific procedures to follow when starting their engines. Some of the concerns when starting an engine are:

- maximum cranking time: to avoid damage to the starter and its components.
- desirable RPM upon start-up (i.e., not to idle or not to over rev.): to give lube oil a chance to reach all the vital areas so that engine parts are not damaged by lack of lubrication.
- cold starting aids: should be used safely so that internal engine parts are not damaged.

Why do diesel engines require cold starting aides? Basically, there are two reasons:

1. Ignition of the fuel in a diesel engine is accomplished by heat of compression. When the temperature drops below 10 C

(50 F.), compression may not be able to bring the cool air to a high enough temperature to ignite the fuel.

2. The diesel fuel itself is less volatile in cold weather and therefore harder to start.

Two common types of starting aides are used with diesel engines:

1. Ether
2. Pre-Heater or Glow Plugs

ETHER

CAUTION, ETHER CAN BE DANGEROUS

— Never handle ether near an open flame

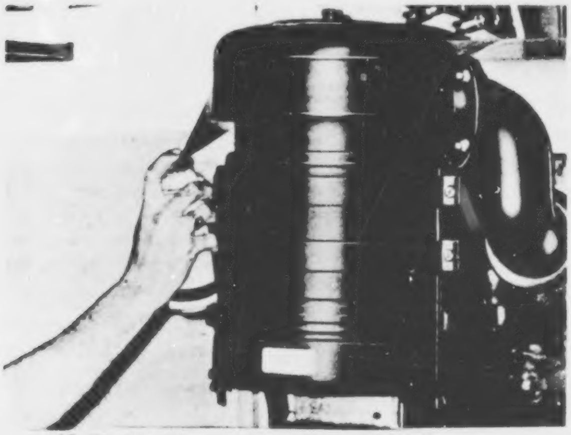
— Do not breathe the fumes

— Do not use excessive amounts of ether. Too much ether will cause unusually high pressures and detonation which can severely damage engine parts. Use ether sparingly.

— Ether must never be used when the electric Glow Plug is on (Manifold Type).

Ether is used as a starting aid because it is very volatile and readily combustible. It is taken into the combustion chambers with the air. Three methods of using ether are:

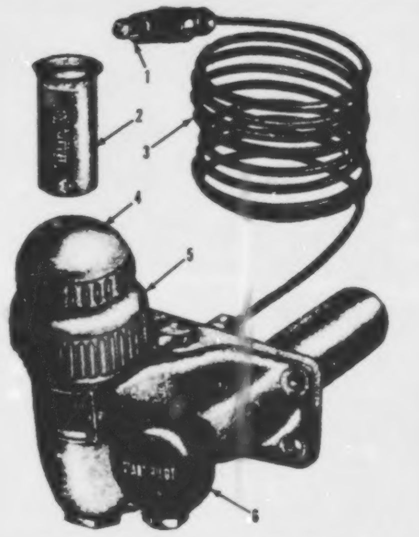
1. Pouring a small amount of liquid ether on a rag and holding it near the air cleaner inlet while the engine is turned over (takes two persons).
2. Spraying a small amount of ether into the air cleaner intake while turning the key to the start position (Figure 2-6).



(2-6) ETHER SPARY APPLICATION

Courtesy of Cummins Engine Co.

3. Applying an ether starting kit (Figure 2-7). The kit has mounted on the control panel a hand operated pump that injects ether vapor directly into the intake manifold. The ether capsule in the kit is good for several starts and then must be replaced.



1 Air Box Fitting
2 Capsule
3 Tubing
4 Piercing Tool
5 Cap
6 Pump

(2-7) ETHER-STARTING KIT

Courtesy of Detroit Diesel, General Motors Corporation

PRE-HEATER AND GLOW PLUGS

A pre-heater in the intake manifold (used in relation with a pump and atomized fuel) or glow plugs in precombustion chambers heat the air that is taken into the combustion chambers to aid in starting.

CAUTION: Never use ether with a pre-heater or glow plugs because severe injury can result from the ether exploding. Use one starting aid, not both.

ENGINE OIL AND THE BATTERY IN COLD STARTING

Two other factors that effect cold starting are the oil and the battery:

Oil — a lighter engine oil, or an oil with lower viscosity, is used in winter weather. Lower viscosity oil makes the engine easier to turn over at colder temperatures.

Battery — Probably the most important point in cold weather starting is to make sure the battery is fully charged. Not only does a battery have a harder job to do in turning over an engine in cold weather, but also it is not as efficient at lower temperatures. For example, a fully charged battery at −9°C (15°F.) is capable of delivering only 70% of its rated current. In addition, keep the terminals clean and the connections tight. Dirty or loose connections offer high resistance to battery current. (Batteries are discussed in detail in Block 9, Electricity).

Below are examples of procedures for start-up (including the use of cold starting aids) and shut down on three common engines that are used in a number of different machines — Detroit Diesel, Cummins Diesel, and Caterpillar Diesel. The starting and stopping procedures discussed for these three engines probably cover those for most other diesel engines.

DETROIT DIESEL
(taken from a Clark-Skidder manual)

NORMAL STARTING

CAUTION: Walk around the machine. Make certain that no one is in the danger area before entering the operator's compartment.

1. Set directional shift lever in NEUTRAL.
2. Depress and release accelerator to reset governor throttle control lever in IDLE position.
3. Turn ignition switch on; rotate key to start position, and very lightly depress accelerator to feed additional fuel. Operate cranking motor no more than 30 seconds at a time to avoid overheating motor.

   CAUTION: If engine fails to start, wait until cranking motor stops rotating before repressing starter switch. Serious damage to the cranking motor may result if this precaution is not complied with. If engine fails to start after four periods of cranking, refer to Operation and Maintenance Manual of engine manufacturer.
4. After engine starts, check oil pressure gauge. If no pressure is indicated within 15 seconds, shut down engine immediately and determine cause.
5. Allow engine to reach operating temperature before driving or operating machine.

COLD WEATHER STARTING
When Colder than 5°C (40°F)

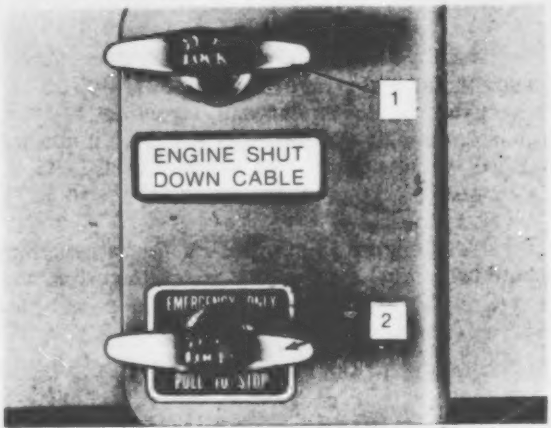
Detroit Diesels are not equipped with cold weather starting aids. It is recommended that starting fluid (ether) be sparingly sprayed into the air cleaner intake as the engine is being started. An alternative to hand-spraying the ether is to install an ether starting kit. See the service manual for directions on how to use the starting kit.

SHUTTING DOWN A DETROIT DIESEL ENGINE

It is important that the engine be idled for three to five minutes before shutting it down to allow the lubricating oil and water to carry heat away from the combustion chambers, cylinder head, bearings, and shafts. Residual heat left after the engine stops can damage many parts ranging from valves to fuel pumps. In addition, the physical stresses from heat expansion and contraction can cause distortion, permanent warping, and gasket failures. It is a good practice to idle any engine long enough to gradually reduce extreme operating temperatures.

To shut down a Detroit Diesel turn the ignition switch off, and then pull the standard engine stop control (Figure 2-8). This operation cuts off the fuel supply. Hold the stop control out until the engine stops operating. After the engine is stopped, move the control back to its original position.

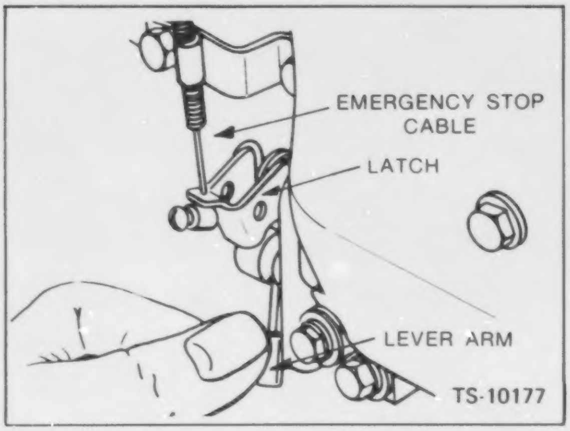
If, after pulling the standard engine stop control, the engine continues to operate, the emergency engine stop (Figure 2-8) must be used. By pulling the emergency engine stop control, the air supply to the engine is cut off thus choking and stopping it.



1 Engine Shutdown Knob 2 Emergency Shutdown Knob (2-8)

Courtesy of Detroit Diesel, General Motors Corporation

Whenever the emergency stop control has been used, it is necessary to manually reset the emergency stop cable latcharm (Figure 2-9) at the engine air intake.



(2-9) RESETTING THE LATCH HANDLE

Courtesy of Clark Equipment Co.

CUMMINS DIESEL

NORMAL STARTING

Cummins normal start procedures are the same as those listed for a Detroit Diesel.

COLD WEATHER STARTING

Cummins Diesels are not equipped with cold weather starting aides. The following cold starting aide procedures are recommended:

1. Pour three tablespoonfuls of ether on a cloth. One man holds the cloth close to the air cleaner intake while a second man cranks the engine.
2. Or spray a small amount of ether into the air cleaner intake while cranking the engine. An alternative cold starting aide is a preheater, available as optional equipment for a Cummins engine. This equipment consists of a single glow plug mounted in the intake manifold, and a hand priming pump to force atomized fuel into the manifold. Depressing a glow plug switch heats the glow plug igniting the fuel that has been pumped into the manifold thereby heating the intake air entering the combustion chamber. See the service manual for directions on how to use the preheater.

CAUTION: Since primary ignition takes place within the manifold, serious damage may result if starting fluid is used with the glow plug hot. Do not use starting fluid in any form with a preheater.

SHUTTING DOWN THE ENGINE

For the same reasons mentioned with a Detroit Diesel, idle a Cummins Diesel for three to five minutes before shutting it down. The pre-shut down idle is especially important with turbo-charged engines. The turbo-charger contains bearings and seals that are subject to the high heat of combustion exhaust gases. While the engine is running this heat is carried away by oil circulation but if the engine is stopped suddenly, the turbo-charger temperature may rise as much as 47°C (100°F). The results of this temperature increase in the turbo-charger may be seized bearings or loose oil seals.

Note on idling an engine: As was just stated, idling an engine for up to five minutes prior to shut down is a good practice. However, long periods of idling are not good for an engine because temperatures in the combustion chamber drop so low that the fuel may not burn completely. Carbon from the unburnt fuel will clog the injector spray holes and the piston rings, and may cause the valves to stick. Also, if the engine coolant temperature becomes too low, raw fuel will wash lubricating oil from the cylinder walls and dilute the crankcase oil. Diluted crankcase oil means that other moving parts of the engine will suffer from poor lubrication. If the engine is not being used, shut it down.

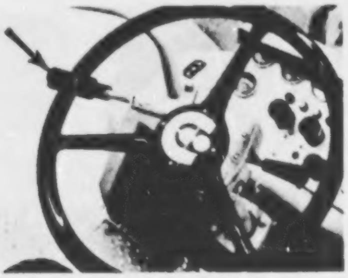
To shut down a Cummins Diesel that has an electric shut down valve, turn the switch key to the off position. The key controls the electric shut down valve and will stop the engine unless the override button on the valve has been locked in the open position. In this case to stop the engine the override button will have to be manually turned clockwise. The engine can always be stopped, under normal conditions, by turning this button.

CAUTION: Never leave the switch key or the override button in the valve open position when the engine is not running. If this is done, fuel from overhead tanks will drain into the cylinders causing hydraulic lock.

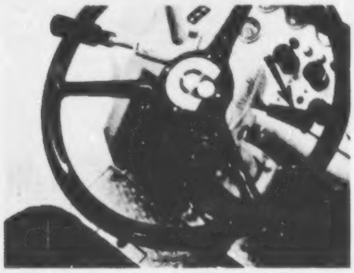
To stop a Cummins engine without an electric shut down valve, turn the manual shut down valve knob.

CATERPILLAR DIESEL ENGINE

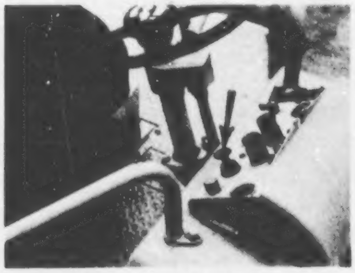
These starting procedures (Figure 2-10) are taken from an operator's manual for Caterpillar loader. Note the two sets of procedures 7 and 8, one for temperatures above 16 C and one for temperatures below 16 C.



1. Place speed & direction control in NEUTRAL.



2. Engage safety lock.

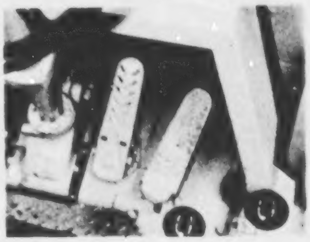


3. Engage parking brake.

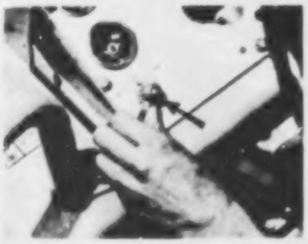
4. Move bucket and equipment controls to HOLD.

5. Turn disconnect switch ON.

Above 60° F (16° C)

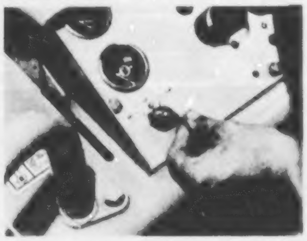


6. Depress accelerator just past detent.

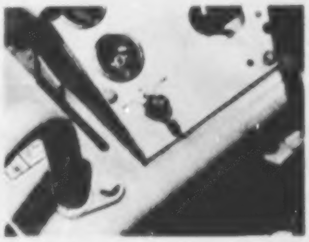


7. Turn HEAT-START switch to START. Release switch when engine starts.

Below 60° F (16° C)



6. Depress accelerator just past detent and turn switch to HEAT for indicated time.



7. Turn switch to START. Release switch when engine starts. It may be necessary to return switch to HEAT until engine runs smoothly.

Starting Aid Chart

STARTING TEMPERATURE	GLOW PLUG HEAT TIME
Above 60° F (16° C)	NO
60° F (16° C)—32° F (0° C)	1 MINUTE
32° F (0° C)—0° F (−18° C)	2 MINUTES
*Below 0° F (−18° C)	3 MINUTES

* Heating of coolant and crankcase oil and starting fluid or extra battery capacity may be required.

NOTE: If engine does not start after cranking for 10 seconds, switch to HEAT for 30 seconds then START. If engine still does not start, let starter cool for 2 minutes then repeat starting procedure.

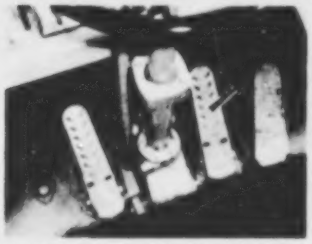
(2-10)

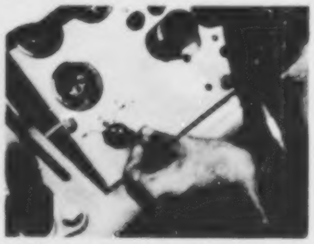
Courtesy of Caterpillar Tractor Co.

The "Heat" mentioned is provided by glow plugs. The Cummins Diesel just discussed had a single glow plug in the intake manifold. This plug ignites atomized fuel pumped in by hand, and the burning fuel heats the air that goes to the combustion chambers. A Caterpillar Diesel has a glow plug for each cylinder. The plugs are located in precombustion chambers and heat the air prior to it going to the combustion chamber.

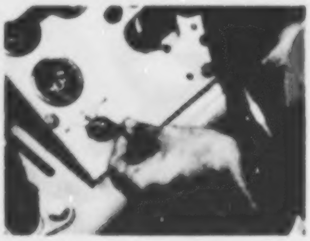
The glow plugs are small heating elements. Depending on how cold it is, they can take from one to three minutes or longer to heat the air sufficiently for starting. If the Cat Diesel won't start with the aid of the glow plugs then starting fluid may be used, as directed in Figure 2-11.

When Starting Fluid is Required


7. Depress accelerator to just past detent.


8. Push in and turn switch to HEAT for indicated time.

9. Push in and turn switch to START, and spray starting fluid sparingly into precleaner while cranking.


10. When engine starts, it may be necessary to return switch to HEAT until engine runs smoothly.

⚠ WARNING

Use starting fluid sparingly. Follow manufacturer's instructions carefully.

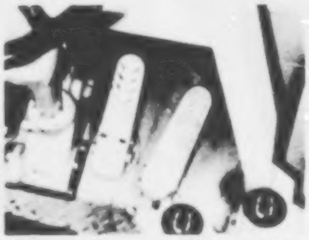
Never switch to HEAT when engine is warm and running.

(2-11)

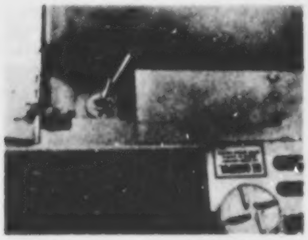
Courtesy of Caterpillar Tractor Co.

STOPPING THE ENGINE

1. Before stopping the engine, operate at reduced load for 5 minutes and stop loader.


2. Reduce engine speed to low idle for 30 seconds.

3. Lift accelerator past detent to stop engine.


4. Turn disconnect switch OFF and remove key.

(2-12)

Courtesy of Caterpillar Tractor Co.

AFTER START CHECKS

After starting the engine, some routine checks should be made. Warm-up checks are virtually the same for all engines, no matter what the make. Below are two examples of warm-up checks taken from Operator's Manuals.

Example 1:

WARM-UP CHECKS
(Clark Equipment Company)

Hold the engine at idle speed for approximately two minutes after starting; then, while the engine continues to warm-up for the next few minutes, perform the following checks (refer to the section, Under 250 Hours Operations, for warm-up procedures):

1. **Engine Oil Pressure Gauge** — 10 to 25 psi at engine idle. If less than 10 psi is registered after 15 seconds of running, shut down the engine and refer to your Engine Service Manual to correct.
2. **Ammeter** — high rate of charge to the battery at engine start; charging rate will decline as the charge is restored in the batteries.

3. **Air Cleaner Indicator** — Check that the red flag indicator is not at its top position, or a new filter or cleaning of this filter is required. Refer to the section, Under 500 Hour Operations, for cleaning instructions.
4. **Converter and Transmission Oil Temperature Gauge** — 130° to 200°F is operating temperature.
5. **Engine Water Temperature Gauge** — 170° to 185°F is operating temperature.
6. **Converter and Transmission Fluid Level** — checked at operating temperature as per instructions in the section, Under 8 Hour Operations.

Visually check for leaks at the drain and fill plugs in the axle assemblies, torque converter and transmission, and at all hose couplings and fittings in the hydraulic, fuel, air intake, brake and cooling systems. Correct all leaking conditions, and repair or replace the gauges that are not functioning before continuing the operation of the machine.

Example 2:

BEFORE DRIVING VEHICLE
(Kenworth Truck Company)

ENGINE WARM-UP

After engine starts, let it idle while you check oil pressure, air pressure and generator output. The engine should be brought up to operating temperature gradually while oil films are re-established between pistons and liners, shafts and bearings.

In colder areas, where temperature is often below 32°F (0°C), the warm-up period for turbo-charged engines is especially important. The chilled external oil lines leading to the turbo-charger will tend to slow oil flow until the oil warms up. Slow oil flow to turbo-charger reduces oil available for bearings. Watch engine oil temperature or pressure gauge for a warming trend before increasing engine idle RPM.

After a couple of minutes of idling at 600 RPM, increase engine speed to 900 or 1000 RPM and continue warm-up. This procedure allows the oil to warm up and flow freely while pistons, liners, shafts, and bearings expand slowly and evenly. Idling the engine too slowly does not allow sufficient splash lubrication of cylinder walls and may result in excessive wearing of pistons and liners. Idling too fast during warm-up will cause too rapid and uneven expansion and also excessive wear.

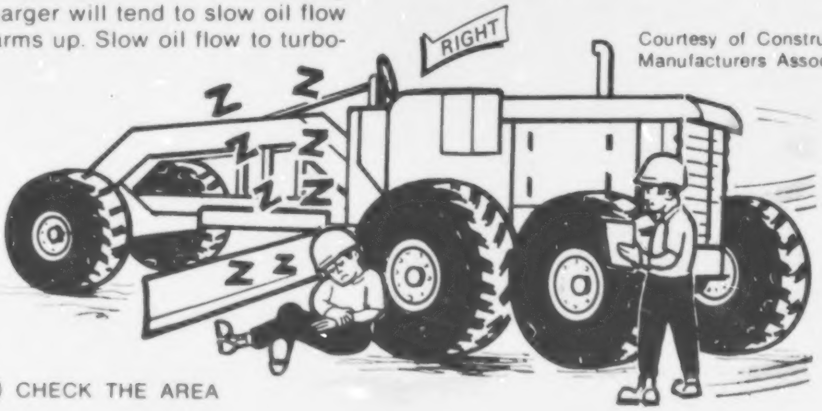
Continue the warm-up until temperature reaches at least 130°F. (54°C), when part throttle operation is permissible. Do not operate at full throttle until temperature is at least 160°F. (71°C).

MOVING VEHICLES

Before attempting to operate any machine, read the operator's manual and become familiar with the purpose and use of all operating controls. Ask an experienced person to show you how to move the machine. Then ask him to observe while you put the machine through a trial run of its operations.

When operating or moving heavy equipment, you should be guided by some fundamental rules of safety that will protect you, your fellow workers, and the machine. The following drawings taken from C.I.M.A. (Construction Industry Manufacturers Association) Safety Manuals, illustrate safe and unsafe operating rules for heavy equipment.

Before mounting the machine walk completely around it making sure that there is no one nearby (Figure 2-13).

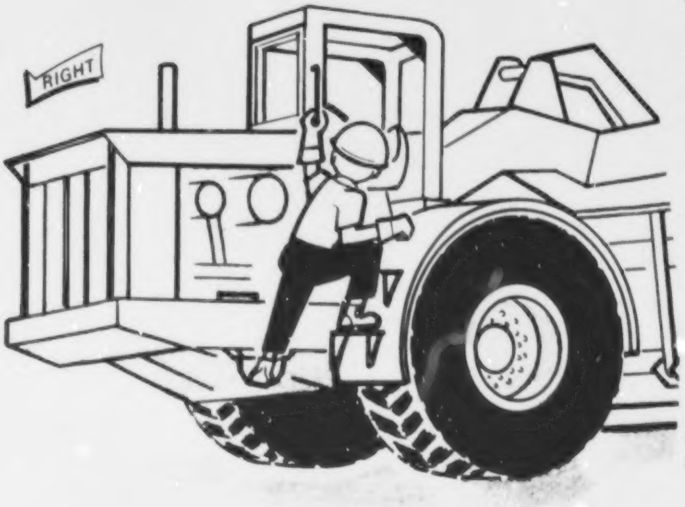


Courtesy of Construction Industry Manufacturers Association (CIMA)

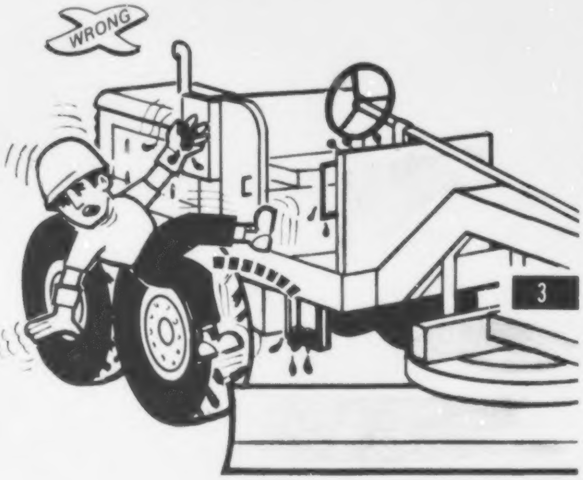
(2-13) CHECK THE AREA

Mount the machine carefully. Always use the steps and grab rails provided (Figure 2-14). Do not grasp the steering wheel or other controls. Don't get on the machine or operate it with wet or greasy hands or with muddy shoes (Figure 2-15). Never try to mount a machine in motion. If someone else has been operating the machine, check the seat adjustment.

Stay seated while operating a vehicle. If the machine has a roll-over structure, you should use a seat belt (if equipped). Also, make sure the seat is adjusted correctly.



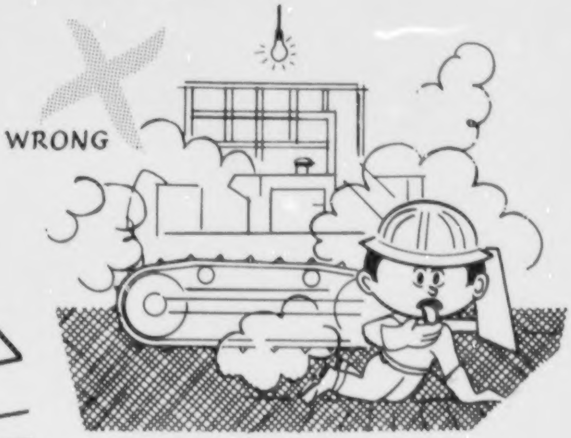
Courtesy of Construction Industry Manufacturers Association (CIMA) (2-14)



(2-15)

Courtesy of Construction Industry Manufacturers Association (CIMA)

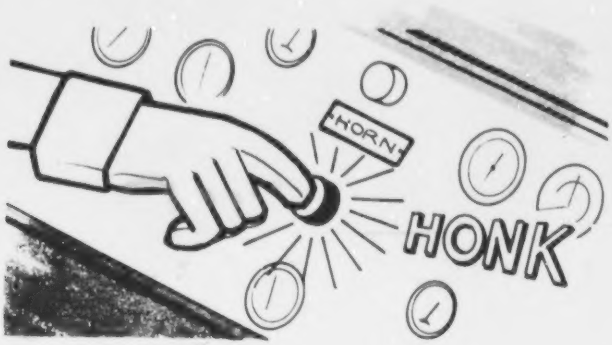
Know that the area is safe for vehicle operation. If it is necessary to start an engine within an enclosed area, provide adequate ventilation. Remember, exhaust fumes can kill (Figure 2-16).



(2-16)

Courtesy of Construction Industry Manufacturers Association (CIMA)

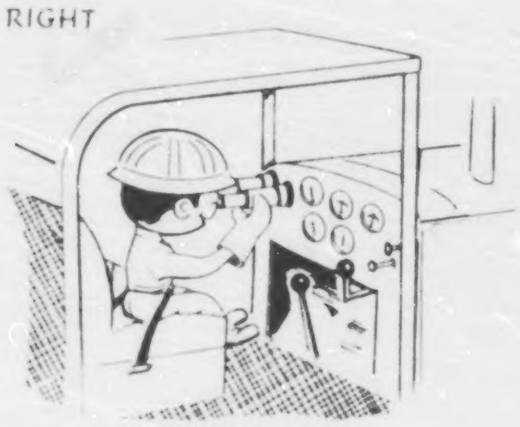
Prior to starting the engine, warn others by sounding the horn (Figure 2-17).



(2-17)

Courtesy of Construction Industry Manufacturers Association (CIMA)

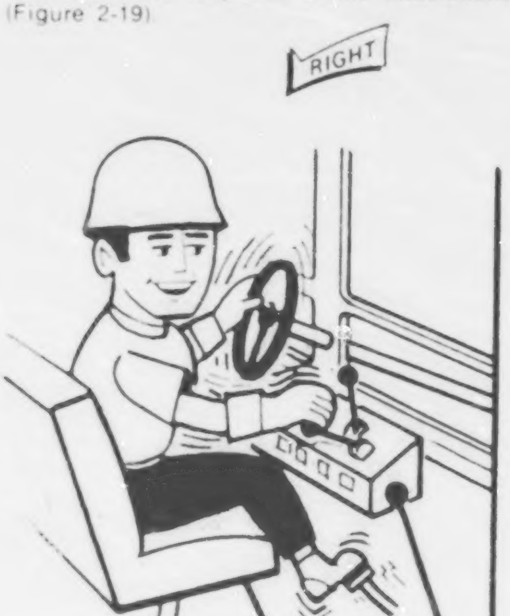
During warm-up check all gauges carefully. Don't operate a vehicle if gauges aren't working (Figure 2-18).



(2-18)

Courtesy of Construction Industry Manufacturers Association (CIMA)

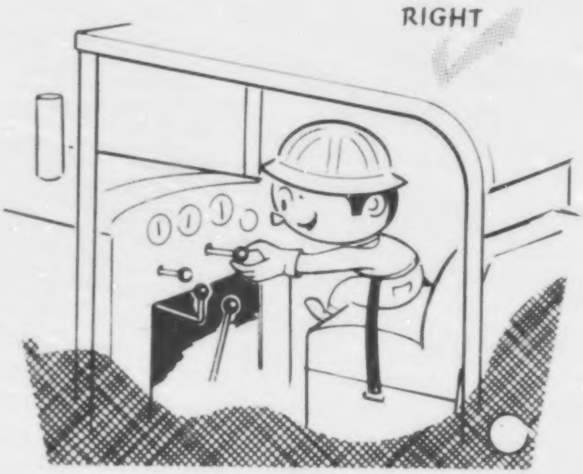
Check the controls, the steering, brakes, working attachment levers. Get the feel of levers and the response of the attachments (Figure 2-19).



(2-19)

Courtesy of Construction Industry Manufacturers Association (CIMA)

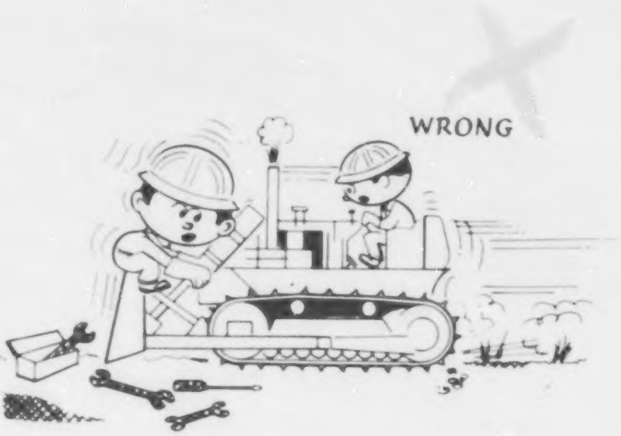
Test the engine speed control (Figure 2-20).



(2-20)

Courtesy of Construction Industry Manufacturers Association (CIMA)

Watch out for the other guy. Prior to moving, warn anyone who is servicing the machine or standing in its path (Figure 2-21).

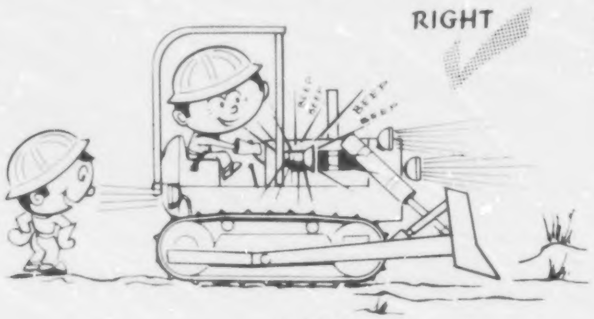


(2-21)

Courtesy of Construction Industry Manufacturers Association (CIMA)

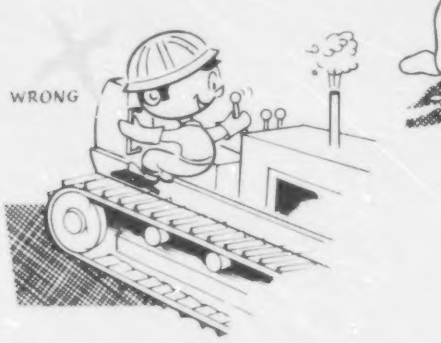
2:16 STARTING, MOVING AND STOPPING EQUIPMENT

Check lights, back-up alarms, emergency brake, and other like equipment (Figure 2-22). Also, test brakes against engine power on machines with a torque converter, and test brakes against ground speed on all tractors.



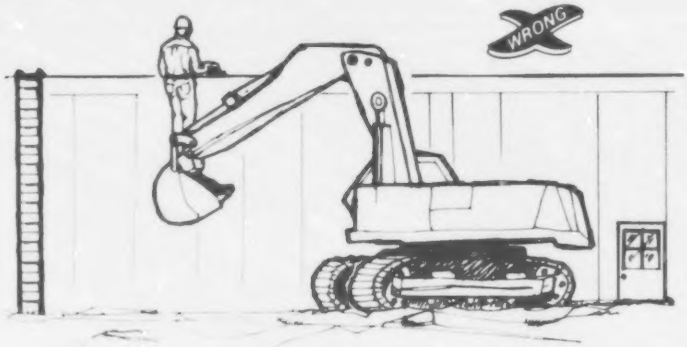
(2-22)

Never operate any piece of equipment from other than the operator's seat (Figure 2-23).

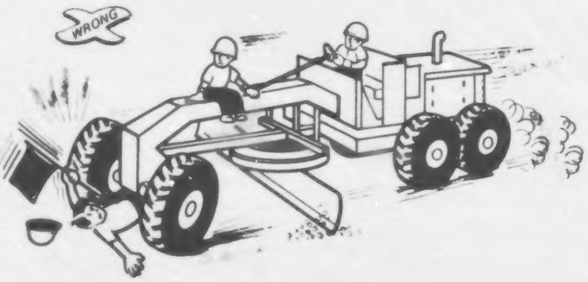


(2-23)

Never allow anyone to ride on the machine, the attachment or the load. This is an extremely dangerous practice (Figures 2-24 and 2-25).

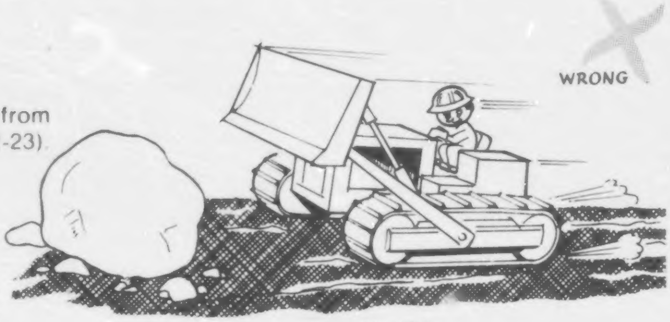


(2-24)



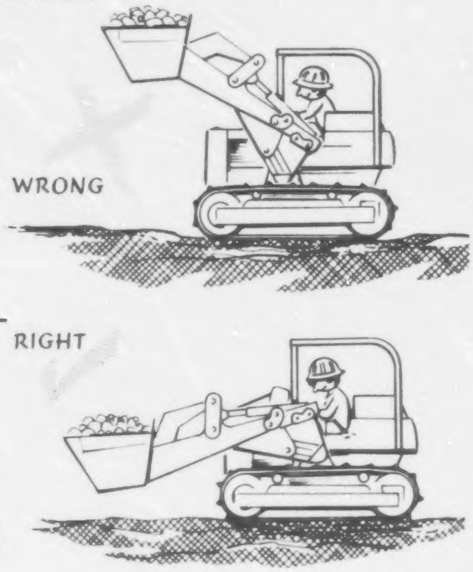
(2-25)

Don't obstruct your vision when moving; keep the attachment low (Figure 2-26).



(2-26)

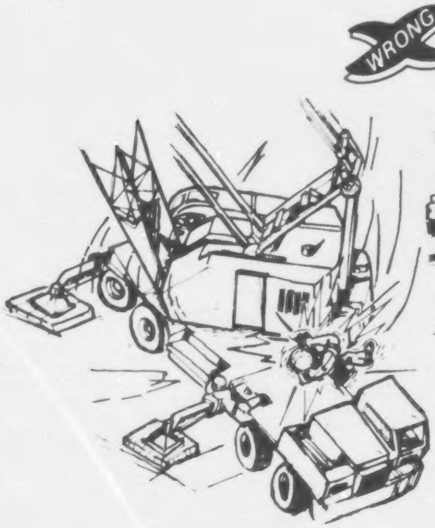
Besides obstructing the vision, carrying the load high also makes the machine top-heavy (Figure 2-27).



(2-27)

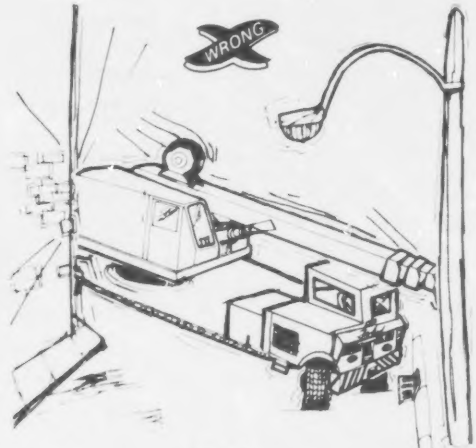
Courtesy of Construction Industry Manufacturers Association (CIMA)

When operating a machine that has limited vision, sound the horn before making any moves. It is also a bystander's responsibility to an operator to stay clear of a moving machine (Figure 2-28).



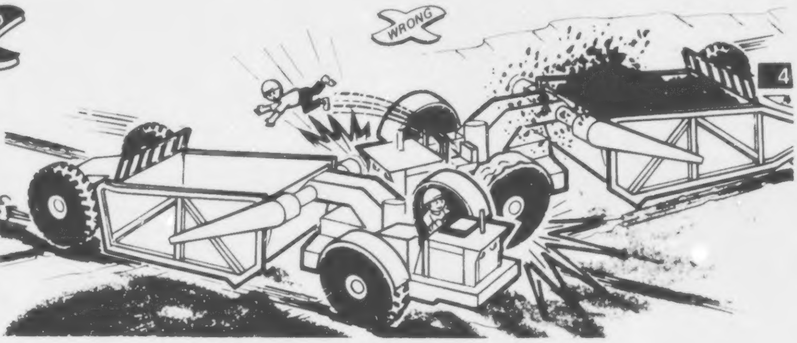
(2-28)

Always be aware of the size of the machine you are moving. It's a good practice to have one or more signal men when moving in a tight spot (Figure 2-29). When driving heavy equipment on a public road make sure clearance flags, lights and other required warnings are on the machine.



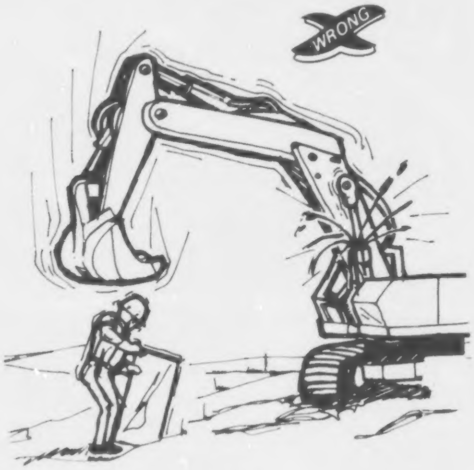
(2-29)

If it is necessary to move equipment through areas where other machines are working, be courteous. Give loaded equipment the right of way (Figure 2-30).



(2-30)

Never swing attachments over men working. Also, never work under a raised attachment without first blocking it securely (Figure 2-31). Remember, all that holds up an attachment is oil trapped in a hydraulic cylinder. If you have to work under it, block it.

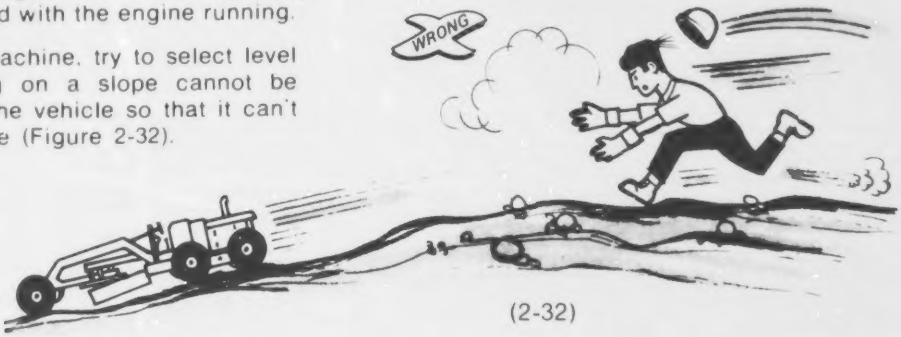


(2-31)

Courtesy of Construction Industry
Manufacturers Association (CIMA)

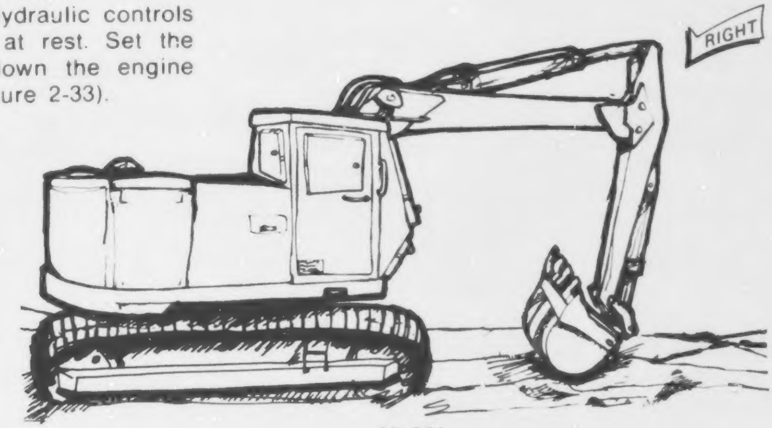
When temporarily parking a machine, set the parking brake and shift the transmission to neutral. If the tractor is equipped with a transmission lock, engage it. Lower all attachments to the ground. Never leave a machine unattended with the engine running.

When parking a machine, try to select level ground. If parking on a slope cannot be avoided, position the vehicle so that it can't roll down the slope (Figure 2-32).



(2-32)

When parking a machine, lower all attachments and relieve all hydraulic controls so that the cylinders are at rest. Set the parking brake and shut down the engine before leaving the cab (Figure 2-33).



(2-33)

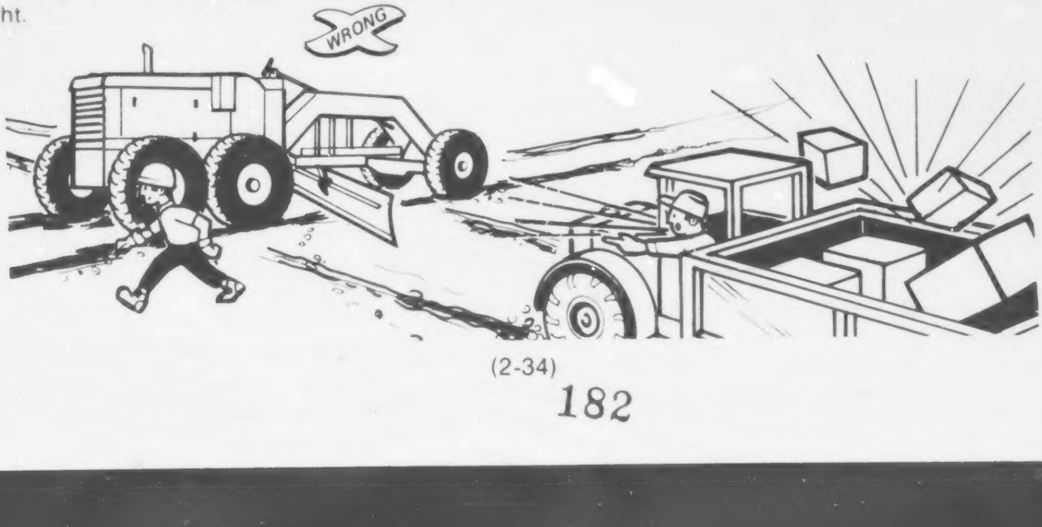
Courtesy of Construction Industry Manufacturers Association (CIMA)

Other good parking practices:

— Park a reasonable distance from other vehicles.

— Haul roads are not parking areas (Figure 2-34). If you must park on one, pick the safest place.

— When parking where traffic is heavy, or when machine is disabled, mark vehicle with flags in the daytime and flares at night.

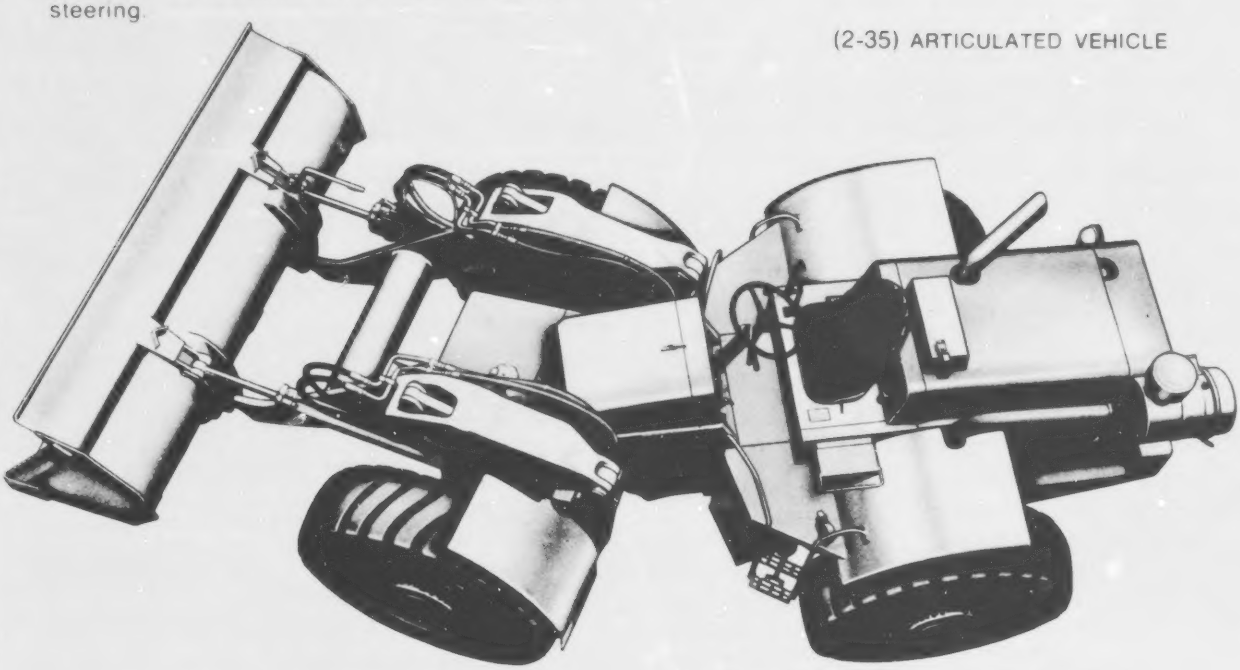


(2-34)

SAFETY PRECAUTIONS WITH ARTICULATED STEERING

Articulated steering means that the vehicle has fixed axles and a frame that hinges in the middle to steer the vehicle (Figure 2-35). Skidders, some graders and wheel loaders are examples of machines that have articulated steering.

(2-35) ARTICULATED VEHICLE



Courtesy of Terex, General Motors Corporation

Machines with articulated steering present a particular safety problem. When the machine hinges or articulates to turn, the two frame sections of the machine come close together in the pivot area on the side nearest the direction of turn. There is no clearance for a person in this pivot area. If someone happened to be there while the machine was turning, he would be crushed. Most articulated machines will have an Area Warning Decal, like the one below, on each side of the front frame. Be absolutely sure when the engine is running or when you're moving an articulated machine that no one is in the pivot area.

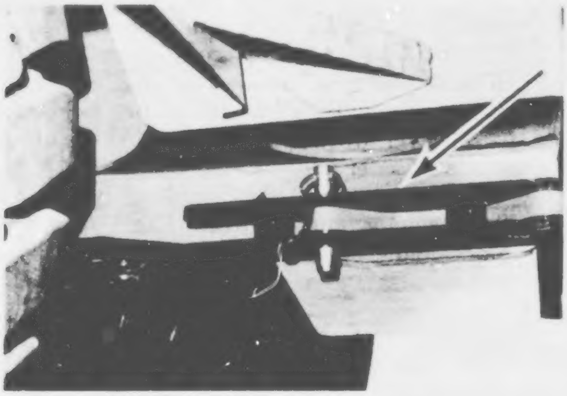
WARNING

NO ROOM FOR A MAN IN THIS AREA
WHEN MACHINE IS TURNED.

DO NOT STAND OR WORK IN THIS
AREA WHEN ENGINE IS RUNNING.

USE SAFETY LINKS WHEN SERVICING
MACHINE.

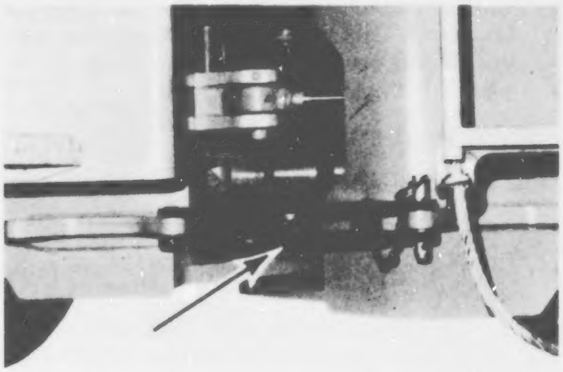
All articulated machines are equipped with a safety bar which will lock the two sections of the machine in a straight ahead position or in a full turn position. Never make any checks or do any service on an articulated machine without first installing this safety bar. Before locking a safety bar, shut off the engine, relieve the hydraulic pressure, and attach a DO NOT OPERATE TAG on the steering wheel. The safety bar is stored alongside the frame (Figure 2-36).



(2-36) FRAME LOCKING BAR IN STORAGE POSITION

Courtesy of Fiat-Allis Construction Equipment Inc

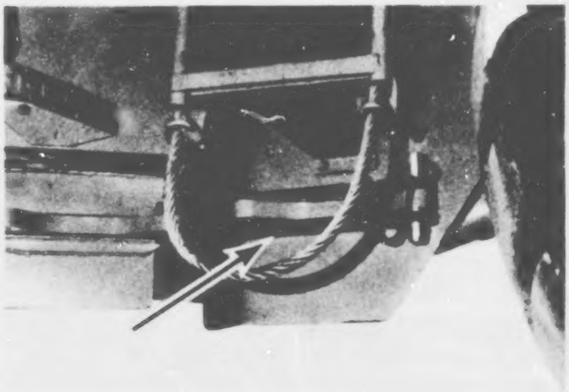
To install the bar in a straight ahead position, remove it from its storage position and attach it to the front frame with the pin provided (Figure 2-37). Besides being used when working on a machine, the straight bar position is also used when transporting the vehicle.



(2-37) FRAME LOCKING BAR IN STRAIGHT—AHEAD POSITION

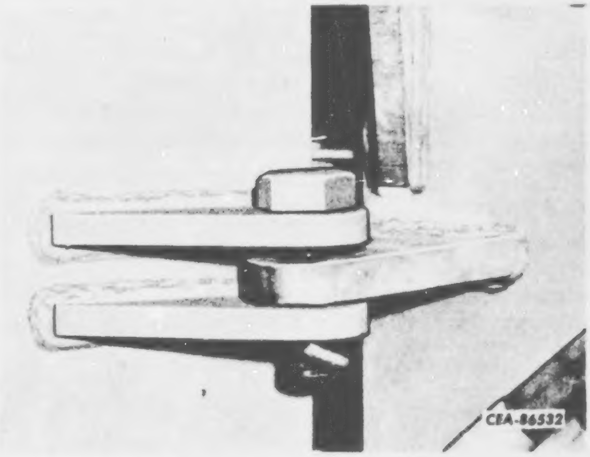
Courtesy of Fiat-Allis Construction Equipment Inc

To lock the two frames in a full turn position some machines use the bar (Figure 2-38), whereas others just insert the pin between the two frames (Figure 2-39).



(2-38) FRAME LOCKING BAR IN ARTICULATED POSITION

Courtesy of Fiat-Allis Construction Equipment Inc.



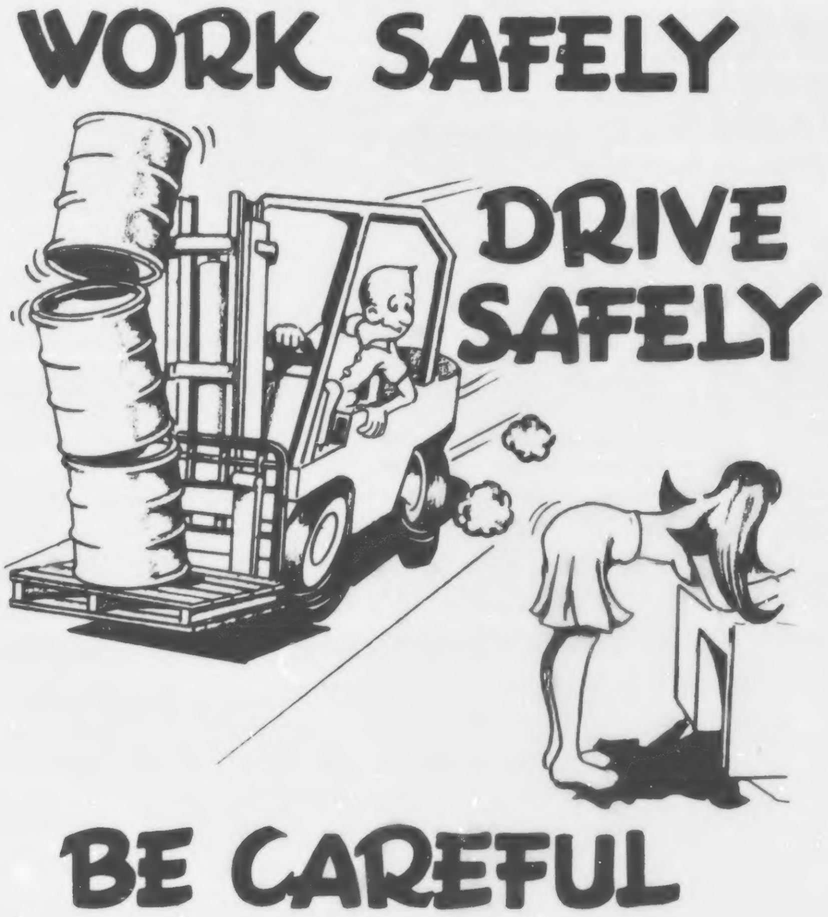
(2-39) PIN ONLY IN FULL TURN LOCK POSITION

Courtesy of International Harvester

COMMON CAUSES OF INJURY IN THE HEAVY DUTY FIELD

To summarize the information on safely moving heavy equipment, always respect the potential danger of big machines. Care and common sense when moving or working on heavy machines will go a long ways in protecting yourself and fellow workers from injury. Keep in mind the following list of the most common causes of injury to those working on or around heavy equipment.

1. Repairing and servicing equipment in dangerous positions.
2. Striking other persons or vehicles with the machine.
3. Unexpected violent tipping of the equipment.
4. Unexpected violent shocks or jars to the machines.
5. Uncontrolled traffic involving other vehicles.
6. Hazards from limbs of trees or overhead obstructions.
7. Leaving earth-moving or other equipment in dangerous positions unattended.



(2-40)

Courtesy of Clark Equipment Co

MACHINE STORAGE

Preparing machinery for storage is an important maintenance procedure. Failure to take the necessary steps to protect certain components prior to storage will result in an expensive overhaul job and a costly time delay in getting the machine back to work.

Every service manual or lubrication and maintenance guide has a section devoted to machine storage. The steps may vary from one machine to another but the purpose is the same: to protect the machine so that there is minimum cost and time delay when the unit returns to work. An example of storage procedures for a Terex wheel loader are given below. The procedures are divided into four categories:

— temporary storage

— extended storage under 6 months

— extended storage over 6 months

— removal from extended storage

TEMPORARY STORAGE

When storing the loader for a period of 30 days or less, the following precautions must be taken:

1. **Inspection and Repair** — Thoroughly inspect and test the unit and make any repairs or adjustments which may be necessary to prepare the unit for service. This will enable you to put the unit back into use immediately after taking it from storage.

2. **Lubrication** — Lubricate the unit completely according to the instructions given in the lubrication section of the manual.

3. **Parking** — After thoroughly cleaning the entire unit park it on a hard, dry, level surface that is free from grease and oil. The oil and grease cause tire deterioration. Lower attachments to the ground and set the parking brake. Cover the exhaust stack to keep out rain water.

4. **Batteries** — Where moderate temperatures are expected, the batteries may be left in the unit. If the unit is not going to be used for about 30 days, the batteries will require a booster at the end of the storage period. In some cases it would be advisable to place the batteries in the shop where they can be inspected and brought up to full charge. In very cold or hot climates, the batteries should be stored where they will be protected from temperature extremes.

5. **Rust Prevention** — Clean and repaint all rust spots. In addition, cover all exposed machine surfaces with a good rust preventive.

6. **Supply Tanks** — Open the drain cocks at the bottom of the unit's air tanks. Fill fuel and hydraulic tanks to prevent moisture condensation within the tanks.

7. **Tires** — Inflate all tires to the correct pressure. During storage, check tire pressures approximately once every two weeks.

8. **Engine** — Consult the ENGINE SERVICE MANUAL for complete information on storing the engine for periods shorter than 30 days.

9. **Transmission** — Fill transmission sumps to the proper level.

EXTENDED STORAGE UNDER SIX MONTHS

When storing the loader for periods of longer than 30 days but under six months, the following procedure must be followed.

Do steps 1, 2, 3, 5 and 6 from temporary storage, in addition to the following:

1. **Batteries** — Remove the batteries from the unit and store them in a suitable place where they can be inspected and charged at least every 30 days or placed on a trickle charger.

2. **Tires** — With the unit up on blocks, deflate the tires to 10 lbs. pressure. Clean off all grease and oil and protect the tires from direct sunlight and water with a suitable cover.

3. **Engine** — Consult the ENGINE SERVICE MANUAL for complete storage data for periods longer than 30 days.

4. **Vents and Breathers** — Remove all vents and breathers and plug the openings with pipe plugs. If this is not possible, seal the vents and breathers with waterproof tape.

EXTENDED STORAGE OVER SIX MONTHS

Same procedures as for extended Storage Under Six Months in addition to the following:

Wheel Bearing — Remove, clean, inspect and repack all wheel bearings (two bearings per wheel).

All procedures for extended storage over six months must be repeated (at least all the ones that can be repeated such as, lubricating and rust proofing) for every six month period the machine is in storage.

Engine storage procedures referred to above would include

1. Properly drain the coolant, or make sure that the cooling system has an adequate antifreeze solution.
2. Remove the injection nozzles. Spray about one ounce of Grade 50 lubricating oil in each cylinder. Crank the engine several revolutions. Clean the injector seats, install new gaskets (if used), and re-install the injectors.

Also, the hydraulic system should be treated in the following way:

Coat the exposed portion of the hydraulic cylinder rods and rod bearings with chassis grease. If the attachment is taken off for storage, secure the cylinders to the tractor to avoid damage.

REMOVAL FROM EXTENDED STORAGE

GENERAL PROCEDURES

1. **Lubrication** — Completely lubricate the unit according to instructions.
2. **Batteries** — Install batteries being sure they have a full charge and the water level is 3/8" to 1/2" above plates.
3. **Tires** — Inflate tires up to the proper level.
4. **Air Tanks** — Check drain cocks to ensure that they are closed.
5. **Fuel, Hydraulic and Steering Cylinder Tanks** — Drain sumps, fill tanks to proper level, remove breather covers and install air breathers. Be sure breathers are cleaned before installation.
6. **Vents and Breathers** — Remove seals and plugs from all breather openings, and install breathers and vents.
7. **Engines** — Consult the engine service manual for instructions on removing an engine from storage.
8. **Paint** — Check unit for rust. Remove all rusty spots and repair rusted areas.
9. **Transmission** — Consult the TRANSMISSION SERVICE MANUAL for instructions on removing the transmission from storage.

QUESTIONS — STARTING, MOVING AND STOPPING EQUIPMENT

1. One of the best sources of information on the operation of equipment is ______________________.

2. What is a pre-start check?

3. What is the purpose of pre-start checks?

4. Good safety practice when making pre-start checks is to:
   - (a) lower all attachments to the ground
   - (b) apply the parking brake
   - (c) attach a DO NOT START TAG to the steering wheel
   - (d) remove the ignition key and open the master switch (if equipped).
   - (e) all of the above

5. It is best to fill the fuel tank at the end of a shift because:
   - (a) it is easily forgotten in the morning
   - (b) condensation in the tank is reduced
   - (c) the tank will hold more when it is warmed up
   - (d) sediment will have time to settle out of the fuel

6. Referring to the walk around inspection diagram for the Caterpillar excavator, what should the track be checked for?

7. Referring to the pre-start checks for the Haul-Pack off-highway truck, what type of brake fluid is used at above 0 F temperatures to top up the brake reservoirs?

8. What is the most important thing to know before starting an engine?
   - (a) how many speeds the transmission has
   - (b) if all the lights are working properly
   - (c) where the starter switch is located
   - (d) how to stop the engine

9. List the three ways diesel engines can be stopped.

10. True or False? The main purpose of an engine governor is to prevent the engine from overspeeding.

11. If the emergency stop is used regularly to stop a Detroit diesel engine, what damage is likely to occur?

12. True or False? An engine decompressing mechanism is intended to be used as an engine starting aid but in an emergency it can be used to stop the engine.

13. To play it safe when starting a diesel engine after an extended storage period or an overhaul, what precaution should be taken?

14. List three things that would cause the sentinel system to automatically shut the engine down.

15. Why do diesel engines require cold starting aids?

16. The two common types of starting aids used with diesel engines are ______________ and ______________.

17. True or False? Ether can be used with a pre-heater or glow plugs.

18. To avoid damaging an electric starting motor, the maximum cranking time when starting the engine should not exceed:
   - (a) 45 seconds
   - (b) 30 seconds
   - (c) 60 seconds
   - (d) 15 seconds

19. When using ether as a cold starting aid, use it ______________ to avoid damaging internal engine parts.

20. Why is it a good practice to idle an engine three to five minutes before shutting it down?

21. If the emergency stop is used on a Detroit diesel, what must be done before restarting the engine?

22. Why are long periods of idling not recommended for diesel engines?

23. How should an engine be brought up to operating temperature?

24. Should the electric solonoid fuel shut-off on a Cummins engine fail, how can the engine be started or stopped?

25. The glow plugs discussed for Caterpillar engines are located in:
   - (a) the intake manifold
   - (b) the intake ports
   - (c) combustion chamber
   - (d) pre-combustion chamber

26. When the pre-start checks are complete, what should you do prior to mounting the machine to start and move it?

27. What is the recommended practice when moving a large piece of equipment in tight surroundings?

28. List the basic steps to be taken to park a machine safely.

29. The steering safety bar used on articulated machines is used for two purposes. One is for safety when working on the machine. What is the other?

30. Why are specific steps taken to prepare a machine for short or extended storage, rather than just parking it?

31. Referring to the storage procedures for the Terex loader, what should be done to the vents and breathers when storing the machine for four months?

ANSWERS — STARTING, MOVING AND STOPPING EQUIPMENT

1. . . . manufacturer's operating manuals.

2. A pre-start check is a systematic series of checks on engine driven equipment prior to starting.

3. To ensure that the machine is in good, safe running condition before beginning its shift.

4. (e) all of the above

5. (b) condensation in the tank is reduced

6. Broken or missing shoes and bolts.

7. SAE J1703

8. (d) how to stop the engine

9.
   1. shut off the fuel
   2. cut off the air
   3. de-compress the cylinders

10. True.

11. Using the emergency stop on a regular basis will damage the scavenge blower seals.

12. True.

13. Remove the air intake and have a piece of smooth plywood ready to cover the inlet.

14.
    1. The engine overheating
    2. Low oil pressure
    3. The engine over-speeding

15.
    1. Ignition of the fuel is accomplished by heat of compression. Cold air when compressed may not reach a high enough temperature to ignite the fuel.
    2. Diesel fuel is less volatile in cold weather.

16. . . . . . ether and pre-heaters or glow plugs.

17. False

18. (b) 30 seconds

19. . . . sparingly . . .

20. To allow the engine to cool off gradually.

21. Go to the engine and manually reset the latch handle.

22. When idling for long periods of time the temperature of the combustion chamber drops so low that fuel does not burn completely causing carbon build up clogging of injector spray holes, clogging of rings and even sticking of the valves.

23. By gradually increasing the idling speed.

24. By pushing the manual override button on the solonoid.

25. (d) pre-combustion chamber.

26. Walk completely around the machine to ensure that all persons are clear.

27. Use one or more signal men to guide the operator.

28.
    - — park on the flattest ground possible
    - — lower all attachments
    - — set parking brakes
    - — shut engine down and neutralize all hydraulic controls

29. To keep the frames parallel when shipping the machine.

30. To protect the machine so that there is minimum cost and time delay when it returns to work.

31. Remove all vents and breathers and plug the openings with pipe plugs. If this is not possible, seal the vents and breathers with waterproof tape.

TASKS

STARTING, MOVING AND STOPPING EQUIPMENT

PRE-START CHECKS

On each of the following heavy equipment units that is available to you, carry out the pre-start and walk around checks listed below:

truck and tractor truck
off-highway truck
crawler tractor (current)
front end loader (articulated)
grader
shovel, log loader or crane
backhoe — excavator

PRE-START AND WALK AROUND CHECKLIST

Make any minor repairs. Do not start the machine if major repairs are needed.

1. Consulting the vehicle's service manual, locate all fluid check points. Check the fluid levels and top up any that are low with the recommended fluid.
2. Check the complete machine for oil leaks, and for fuel and coolant leaks.
3. Look to see if there is a "Do Not Operate" Tag(s) on the controls.
4. Check the machine over for missing or loose components.
5. On wheel machines visually check tire condition and pressure.
6. On track machines check for missing or loose track shoes and track components. Also check the track tension.
7. Set parking brakes.
8. Put controls in neutral.

START, MOVE AND SHUT DOWN VEHICLES

On each of the above heavy equipment units that is available to you, carry out the start, move and shut down procedures listed below.

1. Before starting locate and check (if equipped) the operation of:
   (a) cold starting aid
   (b) normal shut down mechanism
   (c) emergency shut down mechanism
2. Start the engine. Check all gauge readings and warning devices.
3. When the gauges read normal, before moving the machine, release the parking brake, check the operation of the brakes, and give a signal for forward or reverse direction.
4. Move the machine in both a forward and reverse direction and activate all working attachments.
5. Park the machine, lower all working attachments, apply the parking brakes and do a normal shut down.
6. Consulting the service manual, prepare one of the above machines for an extended shut down.
7. On a machine with articulated steering install and remove a steering safety rod.

BLOCK
3

Principles and Theory of Hydraulics

PRINCIPLES AND THEORY OF HYDRAULICS 3:1

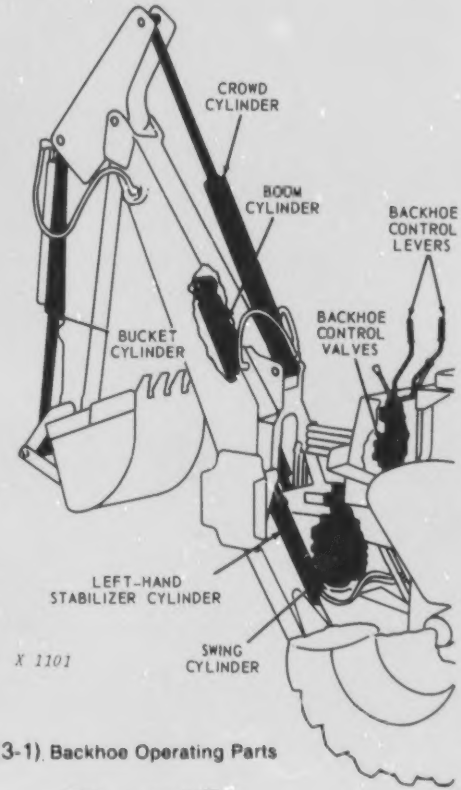
Hydraulics is the science of transmitting force and motion by a confined fluid. The material in this block is intended as a basic introduction to hydraulics. At a later stage in training the subject will be dealt with in greater detail.

A trend in modern machinery has been to replace manually operated components with hydraulically operated ones. Virtually every modern heavy duty machine uses one or more hydraulic systems.

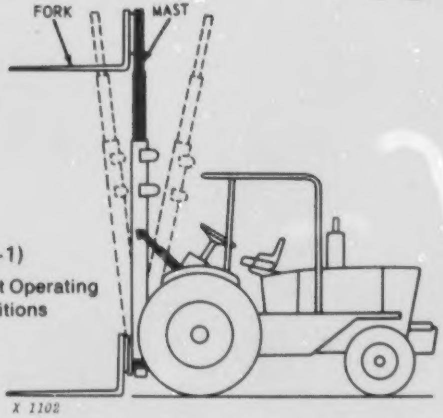
Below are some of the common applications of hydraulics.

Brakes	— Many machines use hydraulic brakes in one form or another.
Steering	— Just about all steering today is hydraulically powered. In fact without hydraulics it would be impossible to steer some of the larger machines.
Transmissions	— All power shift transmissions use hydraulics to obtain speed and ratio changes.
Working and Attachments	— Buckets, blades, rippers, hoists, winches, are all hydraulically operated.
Propel	— Hydraulic propel has been used on many small machines such as agriculture tractors, and is now becoming very popular on larger equipment such as excavators. John Deere makes one of its dozers with hydraulic propel and steering combined.
Winches	— Hydraulically driven winches are becoming more popular, both for tractor-mounted and hoist winches.

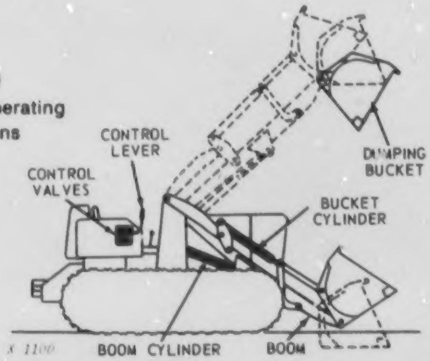
Examples of hydraulically operated working attachments are shown in Figure 3-1.


CROWD CYLINDER
BOOM CYLINDER
BACKHOE CONTROL LEVERS
BACKHOE CONTROL VALVES
BUCKET CYLINDER
LEFT-HAND STABILIZER CYLINDER
SWING CYLINDER
X 1101

(3-1). Backhoe Operating Parts


FORK
MAST
X 1102

(3-1)
Forklift Operating Positions


CONTROL LEVER
CONTROL VALVES
DUMPING BUCKET
BUCKET CYLINDER
BOOM CYLINDER
BOOM
X 1100

(3-1)
Loader Operating Positions

Courtesy of John Deere Ltd.

The reasons for the popularity of hydraulic systems can be seen by looking at their advantages:

1. Hydraulic systems are simple in construction. A few basic hydraulic components will replace complicated mechanical linkages. With less moving parts, there are fewer points of wear.
2. Since hydraulic systems are controlled by relief of safety valves, vital parts of the system are protected from damage.
3. Hydraulically operated parts move very smoothly.
4. Hydraulic systems give a wide range of speed and force.
5. Hydraulic force is multi-directional; it can push, pull or rotate.

Of course, no system is without some disadvantages:

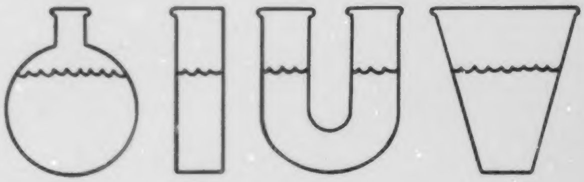
1. Hydraulic systems are subject to leaking. When a hydraulic system is working, it is submitted to high pressures, shock loading and heat, and leaks can occur.
2. Heat from friction in a hydraulic system causes some loss of efficiency.
3. Hydraulic systems have to be kept clean. They must be protected against rust, corrosion, dirt, and oil contamination, any of which can ruin their precision parts.

BASIC PRINCIPLES OF HYDRAULICS

A hydraulic system in a machine operates according to a few, simple principles:

- Liquids have no shape of their own.
- Liquids will not compress.
- Liquids transmit applied pressure in all directions.
- Liquids provide great increases in work force.
- Liquid displaced is equal to liquid gained.

1. Liquids have no shape of their own; a liquid takes the shape of its container (Figure 3-2).

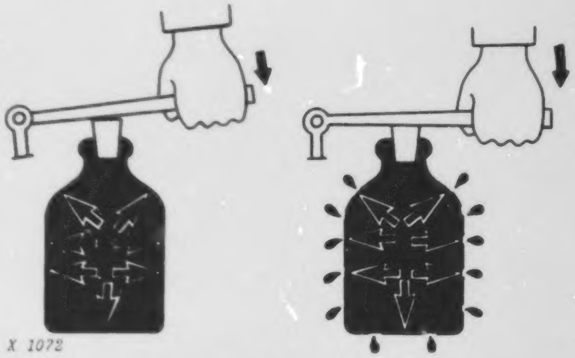


(3-2) – Liquids Have No Shape of Their Own.

Courtesy of John Deere Ltd

Having the property of shapelessness, oil in a hydraulic system will flow in any direction and into a passage of any size or shape.

2. Liquids will not compress. For example, if the cork of a tightly sealed jar was pushed down, the liquid in the jar would not compress. The jar would shatter first. For obvious safety reasons, it's not recommended you try this experiment (Figure 3-3).



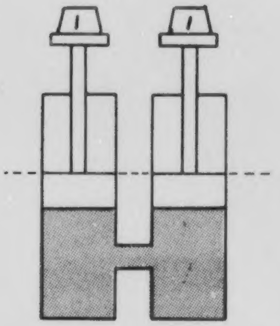
(3-3) Liquids Will Not Compress

Courtesy of John Deere Ltd

NOTE: to be totally accurate it should be pointed out that liquids will compress slightly under pressure (1/2 to 1% at 1000 lbs. per sq. in.). In the present discussion, however, fluids will be considered incompressible.

3. Liquids transmit applied pressure in all directions. The experiment in (2) shattered the glass jar and also showed how liquids transmit pressure in all directions when they are put under compression. Here is another experiment:

   Take two cylinders of the same size (one square inch) and connect them by a tube (Figure 3-4). Fill the cylinders with oil to the level shown. Place in each cylinder a piston which rests on the columns of oil. Now press down on one cylinder with a force of one pound. This pressure is created throughout the system, and an equal force of one pound is applied to the other piston, balancing the 1 lb. weight put on the second cylinder.

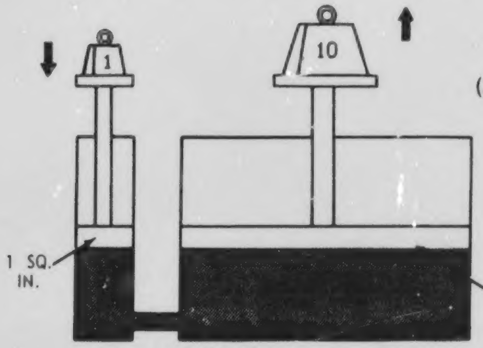


(3-4)

Courtesy of John Deere Ltd.

   This experiment shows that when pressure is applied to one area of a confined liquid, the liquid will spread that pressure to all its other areas. When 1 pound of pressure is applied to the area of oil in the left hand cylinder, the oil spreads the 1 pound pressure to the part of itself in the other cylinder, making the pressure the same throughout the liquid.

4. Liquids provide great increases in work force. Take two cylinders of different sizes and connect them, as shown in Figure 3-5.

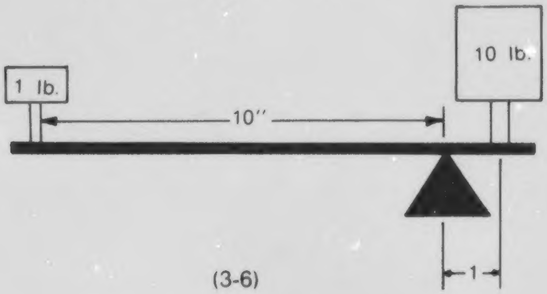


(3-5)

Courtesy of John Deere Ltd.

   The first cylinder has a surface area of one square inch and the second has a surface area of ten square inches. A force of 1 pound is put on the piston in the smaller cylinder. Once again the one pound per square inch pressure is spread throughout the oil. Since the larger cylinder has 10 square inches at its surface, each one of those 10 square inches exerts a force of 1 pound. Together they exert a force of 10 pounds, the force needed to balance a 10 pound weight. In this way the fluid has greatly increased the work force; an input force of 1 pound has given an output force of 10 pounds.

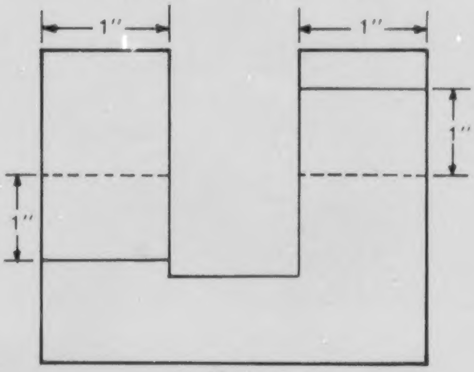
   A work force increase made hydraulically, as in the above example, is similar to a work force increase that can be achieved by mechanical leverage. In the following diagram the 1 pound force acting at 10" from the fulcrum will balance a 10 pound force acting at 1 inch from the fulcrum.



(3-6)

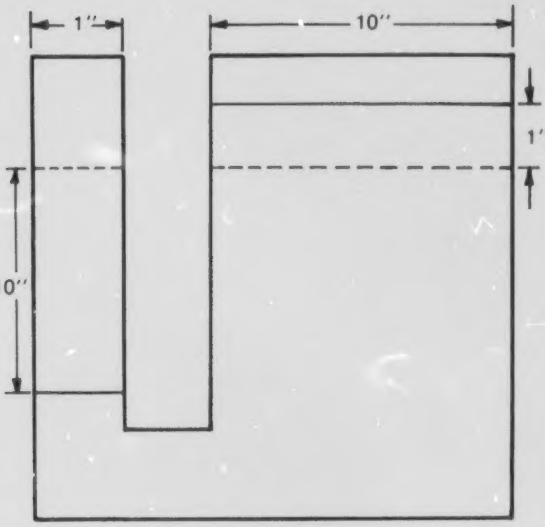
5. In a confined system of joining cylinders the amount of fluid displaced from one cylinder is equal to the amount of fluid gained by the other cylinder. For example:

   (a) When the cylinders (i.e., the pistons) are of equal size, movement of one piston will cause an equal movement in the other piston (Figure 3-7).



(3-7)

(b) When the cylinders are of unequal size, the smaller piston will move farther than the larger one. In the example below the 1" diameter piston moves 10 inches while the 10" diameter piston moves 1 inch. The fluid lost from the first cylinder, though, is equal to the fluid gained by the second (Figure 3-8).



(3-8)

Note the factor of piston speed here. Since the fluid is displaced by one cylinder and gained by the other at the same time, the smaller piston travels 10" in the same time it takes the larger piston to travel 1". The smaller piston therefore travels much faster (10 times faster).

In points 4 and 5 above, fluid was confined between two interconnecting cylinders. In point 4 force was transmitted by the fluid; in point 5 motion was transmitted. Now combine the two points and you have force and motion applied to one cylinder (master cylinder) transmitting a force and motion to the other cylinder (working cylinder). The amount of force and motion transmitted to the working cylinder depends on the relative sizes of the two cylinders. Such an arrangement is a basic confined hydraulic system as would be found in hydraulic brakes. The brake master cylinder sends force and motion by fluid to operate the brake wheel cylinders.

Note that a confined hydraulic system is being discussed here. A circulating hydraulic system using a pump and reservoir will be discussed later.

PRESSURE, FORCE AND AREA

The words pressure, force and area were used above when describing the experiments that demonstrated the basic principles of hydraulics. Given here is a definition of these hydraulic words and a formula that shows the relationship between the two.

Force — a push or a pull measured in units of weight (lbs.).

Area — the surface space on which a force is applied. Measured in sq. ins.

Pressure — a force applied to a certain area. The force is measured in lbs., and the area it is applied to in square inches. Pressure is measured in pounds per square inch (P.S.I.); i.e., if 30 lbs. of pressure were applied to 10 square inches, the pressure would be 30 ÷ 10 = 3 lbs. per square inch.

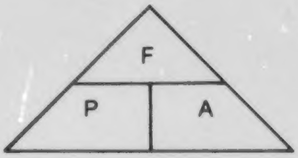
The following relationships exist between pressure force and area.

Pressure $= \frac{\text{Force}}{\text{Area}}$; $P=\frac{F}{A}$

Force $=$ Pressure $\times$ Area; $F = P \times A$

Area $= \frac{\text{Force}}{\text{Pressure}}$; $A=\frac{F}{P}$

An easy way to remember these formulas is by using the following triangle.



To understand how it works, look at the triangle as you read the formulas:

$$F = P \times A \qquad P=\frac{F}{A} \qquad A=\frac{F}{P}$$

To do basic hydraulic problems involving P, F, and A, you have to know how to square a number and how to use the formula for the area of a circle.

1. To square a number multiply the number by itself.

   Examples:

   (a) 2^2 (read two squared) $= 2 \times 2 = 4$

   (b) $3^2 = 3 \times 3 = 9$

   (c) $14^2 = 14 \times 14 = 196$

2. Area of a circle $= \pi r^2$ where π is equal to $\frac{22}{7}$ or 3.14, and r is the radius of the circle. The formula can be written:

   $$\text{Area of a circle} = \frac{22}{7} \times r \times r$$

   If the diameter (D) rather than the radius of the circle is given this formula can be used:

   $$\text{Area of a circle} = .79 \times D^2$$

Example Area problem: What is the area of a circle of 2″ diameter?

$A = .79 \times D^2$

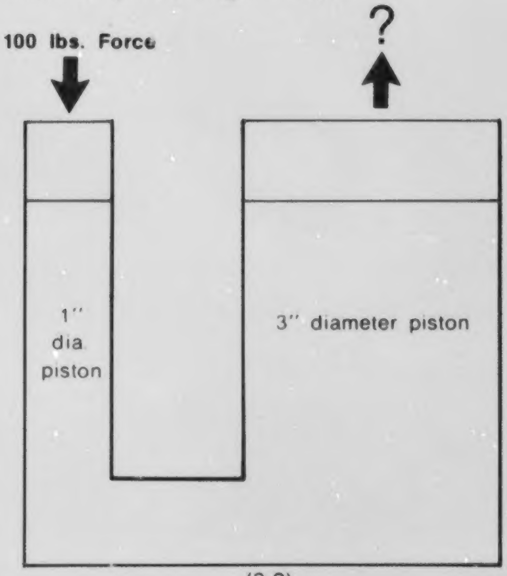
$A = .79 \times 2'' \times 2''$

$A = .79 \times 4$ sq. in.

$A = 3.16$ sq. inches

EXAMPLE PRESSURE, FORCE, AND AREA PROBLEMS

If a 100 lb. force is applied to a 1″ diameter piston, what force will be exerted on a 3″ diameter piston (Figure 3-9)?



(3-9)

Solution

Knowing that $F = P \times A$, you must find the pressure (P) and the area (A) of the large cylinder before you can find the force (F).

Step 1 — First of all the area of each piston should be found. Since the diameters are given, use the Area formula with the diameter in it.

(a) $A = .79D^2$

$A = .79 \times 1 \times 1$

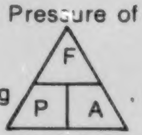
$A = .79$ sq. in. is Area of small cylinder top.

(b) $A = .79\ D^2$

$A = .79 \times 3 \times 3$

$A = .79 \times 9$

$A = 7.11$ sq. in. is Area of large cylinder top.

Step 2 — Now find the Pressure of the small cylinder using , since you know the F and the A. The pressure in the large cylinder will be the same.

$$P = \frac{F}{A}$$

$$P = \frac{100}{.79}$$

$P = 126.5$ P.S.I.

That means that the pressure throughout the system is 126.5 P.S.I.

Step 3 — Since you now know the (P) and the (A) for the large cylinder, you can find the force.

$F = P \times A$

$F = 126.5 \times 7.11$

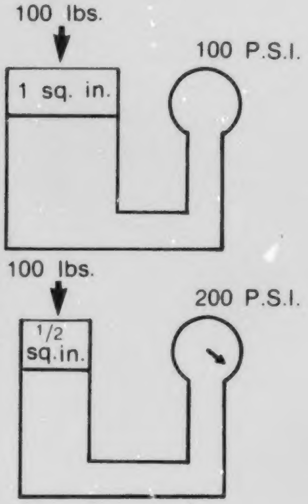
$F = 899.4$ lbs.

899.4 pounds will be exerted at the larger cylinder. Thus the work force has increased from 100 lbs. to 899.4 lbs.

PRINCIPLES OF HYDRAULIC CYLINDERS

The formula, $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$, can be used to verify basic principles of hydraulic cylinders.

1. Given the same applied force, as the area of the cylinder decreases, the pressure increases. In Figure 3-10 the pressure increases because the force is concentrated on less area. Instead of the 100 lb. pressure being applied to 1 sq. in., it is applied to $^{1}/_{2}$ sq. in.

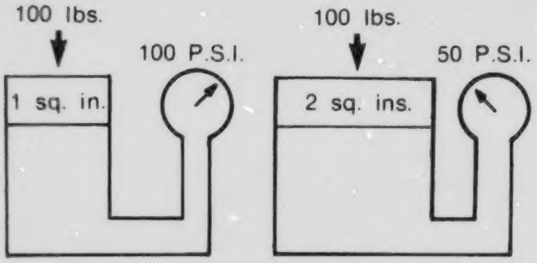

100 lbs.
1 sq. in.
100 P.S.I.
100 lbs.
1/2 sq.in.
200 P.S.I.

$$P = \frac{F}{A} = \frac{100}{1} = 100 \text{ P.S.I.}$$

$$P = \frac{F}{A} = \frac{100}{.5} = 200 \text{ P.S.I.}$$

(3-10)

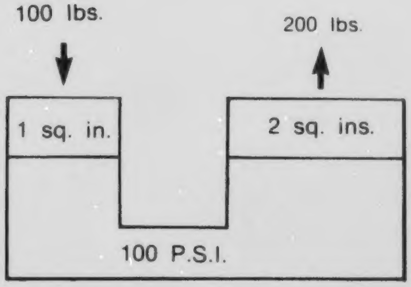
2. Conversely, if the size of the cylinder increases, the pressure decreases (Figure 3-11).


100 lbs.
100 P.S.I.
1 sq. in.
100 lbs.
50 P.S.I.
2 sq. ins.

(3-11)

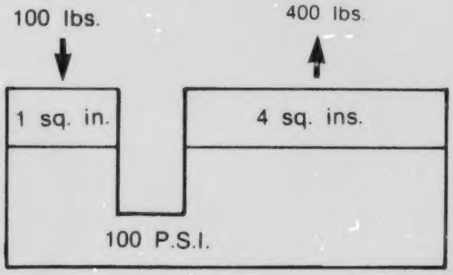
$$P = \frac{F}{A} = \frac{100}{2} = 50 \text{ P.S.I.}$$

3. If the fluid pressure remains constant and the area of the working cylinder increases, the outward force on the working piston increases because there are more square inches of force acting on it (Figure 3-12).


100 lbs.
200 lbs.
1 sq. in.
2 sq. ins.
100 P.S.I.

$$F = P \times A = 100 \times 2 = 200 \text{ lbs.}$$

(3-12)


100 lbs.
400 lbs.
1 sq. in.
4 sq. ins.
100 P.S.I.

$$F = P \times A = 100 \times 4 = 400 \text{ lbs.}$$

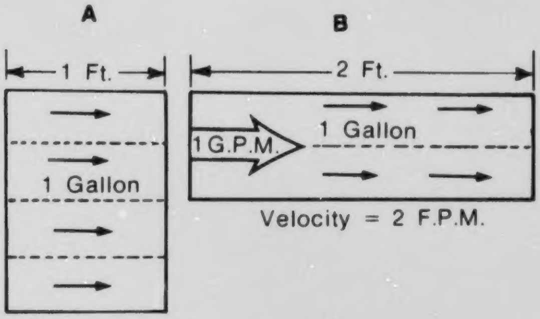
HYDRAULIC FLOW

Flow is defined as the movement of a fluid. The discussion so far has considered confined hydraulic systems of one cylinder or of two interconnecting cylinders where fluid flows back and forth between the cylinders. In a circulating hydraulic system fluid flows from a reservoir to a pump to a working cylinder and back to the reservoir again. Flow is measured by velocity and by flow rate.

1. **Velocity** is the average speed of a fluid past a given point. Velocity is measured in feet per second (F.P.S.) or feet per minute (F.P.M.). Flow velocity must be taken into account by a mechanic when sizing hydraulic lines.
2. **Flow rate** is the measure of the volume of fluid that passes a point in a given time. It is usually measured in gallons per minute (G.P.M.).

FLOW IN LINES

Velocity and flow rate are closely related. Given that a fluid is traveling through a certain line size, flow rate will determine the velocity at which fluid will travel. To illustrate this point; pump a fluid at a constant rate of 1 G.P.M. through two 1 gallon pipe sections of different diameter. Each section will be emptied and refilled every minute (Figure 3-13).



Velocity 1 F.P.M.

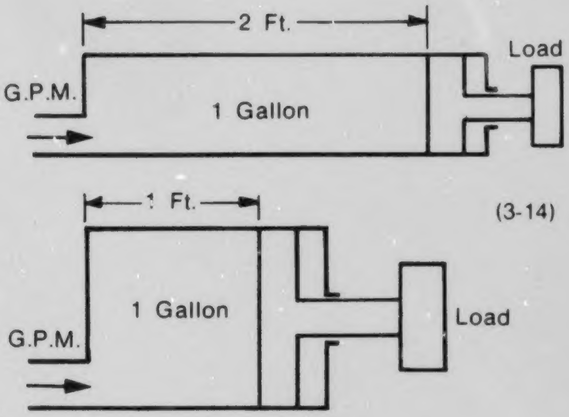
Velocity = 2 F.P.M.

(3-13)

To have a flow rate of 1 G.P.M. the fluid in pipe section A has a velocity of 1 foot per minute. To have the same flow rate of 1 G.P.M. the fluid in pipe section B must travel at 2 feet per minute. Thus to get the same flow rate through different size pipes, the smaller the diameter of the pipe, the faster the velocity of the fluid has to be to move through it.

When fluid travels through a pipe, friction is created; the greater the velocity of the fluid, the greater the friction. Since line size is directly related to fluid velocity, it is important that lines be of adequate diameter so that the fluid does not travel at too high a speed and cause overheating in the line. For this reason always replace hydraulic lines with the same size as the originals.

FLOW IN CYLINDERS



(3-14)

In the two cylinders in Figure 3-14 one G.P.M. is pumped into each cylinder. The piston in the smaller diameter cylinder must travel twice as far, and therefore twice as fast, as the piston in the larger diameter cylinder. The smaller piston can do this because the velocity of the fluid in its cylinder is twice as fast. This example illustrates that given an equal flow rate of fluid into two cylinders the piston in the smaller cylinder travels farther and faster than the piston in the larger.

However, the advantage is not all on the side of the smaller cylinder. Remember that the bigger the cylinder area, the bigger the force on the cylinder. The piston in the larger cylinder will not move as fast or as far, but it moves with a greater force. A counter balance exists; what you get in speed you give up in force.

Manufacturers have this counter balance in mind when choosing the size of a hydraulic cylinder. They must balance the load a piston is expected to lift against the speed and distance it has to move. Looking at the hydraulic cylinders on the back hoe in Figure 3-1, the boom cylinder, the crowd cylinder and the bucket cylinder are all a different size and length. Each of the hoe's cylinders is designed weighing the force with which its component acts against the speed and distance the component must travel.

HYDRAULIC OIL

The oil in a hydraulic system is the medium which transmits power. It is also the system's lubricant and coolant. Although the manufacturer's service manual will say what type of oil to use in its hydraulic systems, it is worth mentioning the factors that go into selecting an oil that will give good performance and long life to a hydraulic system.

1. **Viscosity** — Viscosity is the measure of fluidity. In addition to dynamic lubricating properties, oil must have sufficient body to provide adequate sealing effect between working parts of pumps, valves, cylinders and motors, but not enough body to cause pump cavitation or sluggish valve action.
2. **Viscosity Index** — Viscosity index reflects the way viscosity changes with temperature. The smaller the viscosity change the higher the viscosity index. The viscosity index of hydraulic oil should not be less than 90.
3. **Additives** — Research has developed a number of additive agents which improve various characteristics of oil for hydraulic systems. These additives are selected to reduce wear, increase chemical stability, inhibit corrosion and depress the pour point. The most desirable oils for hydraulic service contain higher amounts of antiwear compounding.

The following are examples of three types of oil that have the viscosity, viscosity index and additives necessary to meet SAE and API service ratings for a hydraulic system.

1. Series 3 Diesel Engine Oil
2. Automatic Transmission Fluid Types. A, F, and Dexron
3. Hydraulic Transmission Fluid C-1 and C-2.

BASIC CIRCULATING HYDRAULIC SYSTEM

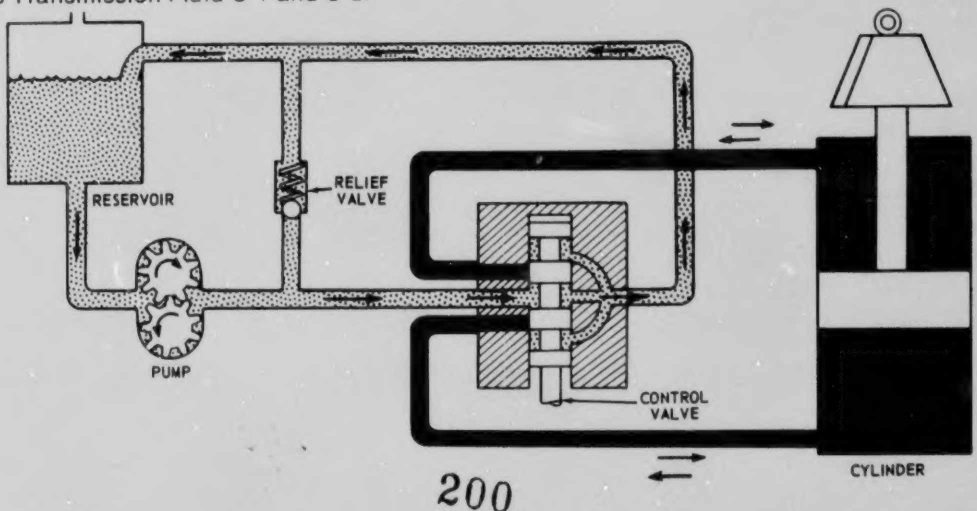
The purpose of a hydraulic system is to convert mechanical energy into hydraulic energy which will perform work. Figures 3-15 shows a basic circulating hydraulic system with the control valve in neutral position.

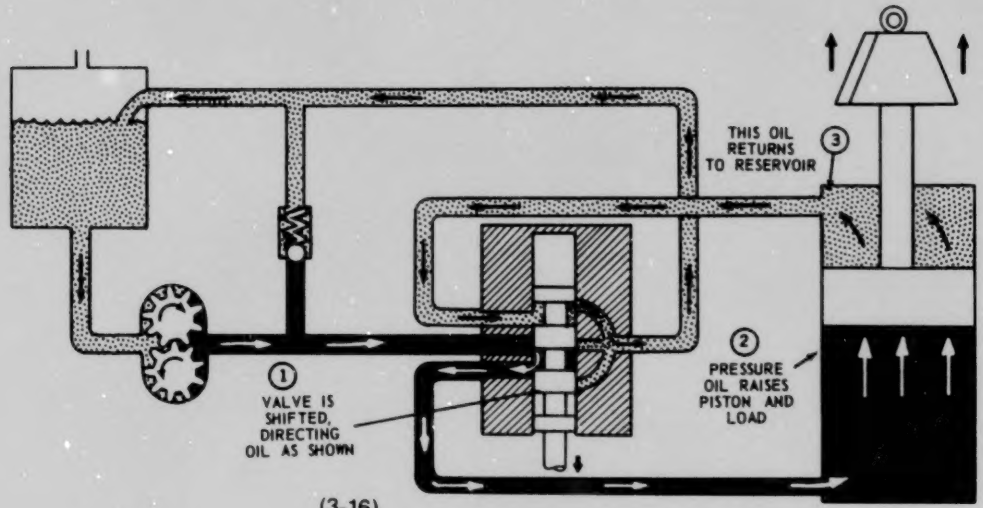
A basic hydraulic system consists of the following parts:

1. **A reservoir** — stores the oil.
2. **The Pump** — supplies the push or force which causes fluid to flow and thus to back up and create pressure. The pump is driven by the engine and is designed to supply a maximum amount of gallons per minute.
3. **Relief Valve** — keeps the system from overpressurizing. A hydraulic system is designed to operate at a certain pressure. The relief valve is set at this pressure. When the setting is exceeded, the valve opens releasing pressure and safeguarding the system from damage.
4. **Control Valve** — directs a flow of pressurized oil from the pump to the cylinder. It also directs the oil coming from the cylinder back to the reservoir.
5. **Cylinder** — converts the hydraulic flow and pressure to mechanical work energy.

Courtesy of John Deere Ltd.

(3-15)



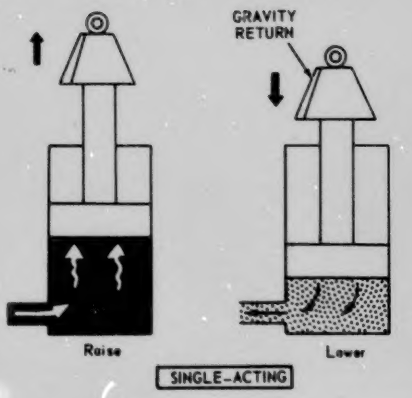

THIS OIL RETURNS TO RESERVOIR
③
②
PRESSURE OIL RAISES PISTON AND LOAD
①
VALVE IS SHIFTED, DIRECTING OIL AS SHOWN

(3-16)

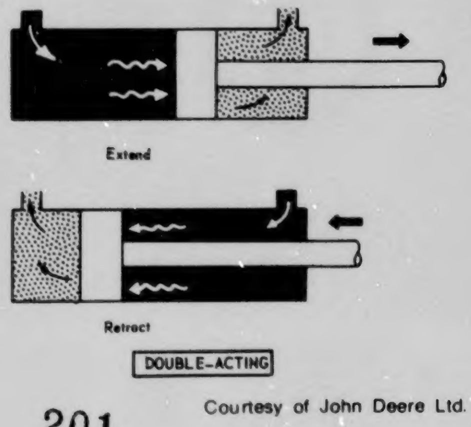
Courtesy of John Deere Ltd.

Figure 3-16 shows the hydraulic system in operation.

The control valve is in the raised position. Oil from the pump flows through the control valve to the bottom of the cylinder where it exerts a force and drives up the cylinder. Oil from the top of the cylinder flows through the control valve and back to the reservoir. There are two ways that the piston can return to its original position. One way is by gravity; if pressure is released from the bottom of the piston the piston will gravity drop and in so doing will push the oil out the bottom of the piston through the control valve and back to the reservoir. A cylinder that operates like this is called single acting (Figure 3-17). The other way of returning the piston is by supplying pressurized oil to the top of the piston and driving it back to the bottom of the cylinder. Pressure is first released from the bottom of the piston and the return driven piston forces the oil out through the control valve to the reservoir. This cylinder is called double acting (Figure 3-17).


GRAVITY RETURN
Raise
Lower
SINGLE-ACTING

(3-17)


Extend
Retract
DOUBLE-ACTING

Courtesy of John Deere Ltd.

HYDRAULIC COMPONENTS

Reservoirs — while reservoirs are the simplest of the components of a hydraulic system, they are vital to its proper operations.

Every hydraulic system must have a reservoir. The reservoir not only stores the oil, it also helps keep the oil clean, free of air, and relatively cool.

CAPACITY OF RESERVOIRS

A reservoir should be compact, yet large enough to:

1. Hold all the oil that can drain back into the reservoir by gravity flow.
2. Maintain the oil level above the suction line opening.
3. Dissipate excess heat during normal operation. (See also "Oil Coolers", which follows.)
4. Allow air and foreign matter to separate from the oil.

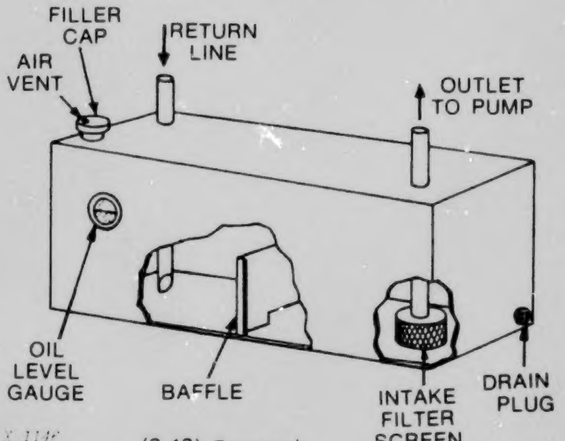
FEATURES OF RESERVOIRS

To serve its purpose, the reservoir (Figure 3-18) must have several features.

1. **Filler Cap** — should be air tight when closed, but may contain an **air vent** which filters air entering the reservoir to provide a gravity push for proper oil flow. The air vent filter must be kept clean to prevent partial vacuums which restrict gravity flow from the reservoir.

   NOTE: Ideally, a system may be designed with a sealed reservoir and no air vent. However, since most systems have changing oil levels and temperatures and different piston sizes, air venting is needed.

2. **Oil Level Gauge** — gives the level of oil in the reservoir without opening it. Dipsticks are still widely used, however.
3. **Baffle** — helps to separate return oil from that entering the pump. This slows the circulation of oil, gives the return oil time to settle, and prevents constant reuse of the same oil. However, no baffle is needed in many modern systems because the same separation of inlet and return oil is achieved by placement of lines and filters.



(3-18) Reservoir

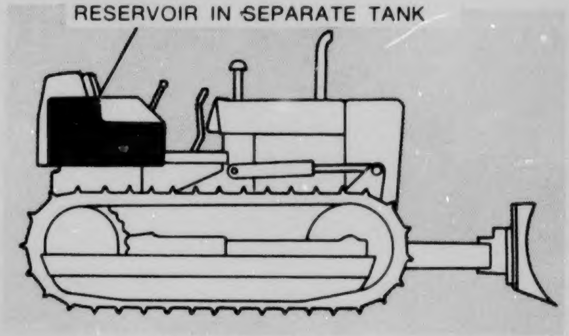
Courtesy of John Deere Ltd.

4. **Outlet and Return Lines** — are designed to enter the reservoir at points where air and turbulence are least. They can enter the reservoir at the top or sides, but their ends should be near the bottom of the tank. If the return is above the oil level, the return oil can foam and draw in air.

   NOTE: Be careful when placing extra returns from auxillary equipment in the reservoir. If not placed correctly, they can cause foaming of return oil.

5. **Intake Filter** — is usually a screen used in series with the system oil filter which may also be installed in the reservoir.
6. **Drain Plug** — allows all oil to be drained from the reservoir. Some drain plugs are magnetic to help remove metal chips and burrs from the oil.

The location of the reservoir depends upon the design of the machine, the available space and the size of the reservoir (Figure 3-19).



(3-19) Courtesy of John Deere Ltd.

FILTERS

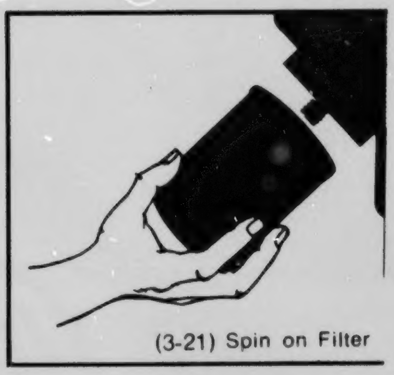
The function of filters in a hydraulic system is to catch and retain contaminants that get into the oil. Since hydraulic oil is a lubricant as well as a power transmitter, the oil must be free of contaminants so as not to score or damage precision parts. Contaminants will inevitably enter into the oil from dust in the air (machines often work in very dusty conditions) and from normal wear which causes chips and burrs to break off from the metal parts. There are many kinds of filters made having a broad range of filtering capabilities. A filter has to be fine enough to catch contaminants, yet still allow the oil to freely circulate through it. Filters will hold only so many bits and particles before they start to restrict the flow of oil, and therefore they must be changed regularly.

Two main types of filters are a cartridge filter that fits into a housing and a spin-on filter threaded onto a housing (Figures 3-20, 3-21).

FILTER ELEMENT
FILTER COVER

(3-20) Cartridge Filter

Courtesty of John Deere Ltd.



(3-21) Spin on Filter

The most common type of filtering system is called a full flow system which filters the oil each time it circulates through a cycle. The number and arrangement of filters will vary from machine to machine. One basic arrangement is to have a filter on the inlet line and another on the return line to the reservoir. The inlet filter will be a course filter called a strainer which will not restrict flow to the pump. The return line will have a finer grade filter that will sift out the contaminants before they get into the reservoir.

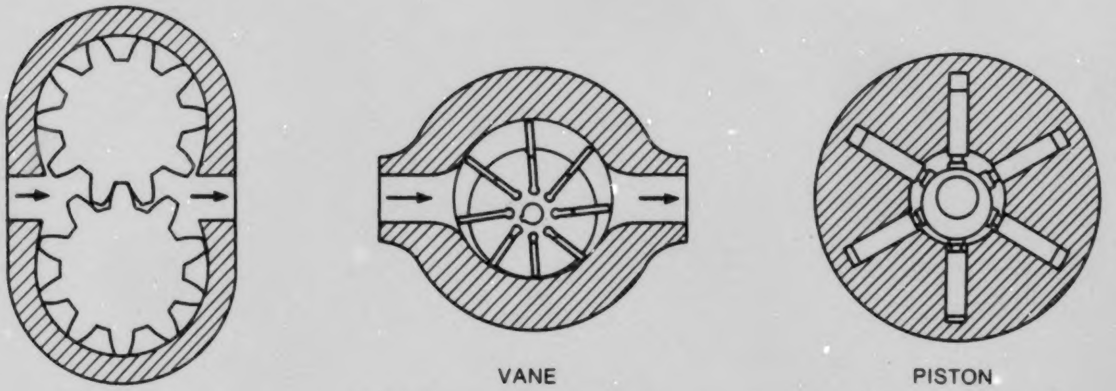
PUMPS

The primary purpose of any pump is to create flow. Pumps work on a principle called displacement; fluid is taken in and then displaced (i.e., made to flow) to another point. Hydraulic pumps are referred to as positive displacement pumps. They not only create flow but support the flow, creating a pressure in the system. The combination of flow and pressure is the source of working power in a hydraulic system.

A hydraulic pump creates positive displacement or pressure in the following way. The pump is constructed to run with close tolerances between the moving and the stationary parts, thereby forming a seal between the inlet and outlet. When the pump applies a force to the fluid on the outlet side of the pump, the fluid can't flow back to the inlet side because of the seal. The fluid, therefore must flow from the outlet. As it does it meets a resistance to flow and in counteracting this resistance a pressure is built up in the fluid.

The output of a pump is rated by the number of gallons per minute that the pump can deliver at a given RPM and pressure. Most pumps are rated at a higher capacity than is needed for the job that they must do. A pump with reserve capacity will wear slower than one without the reserve, and when it does begin to wear it has some margain before falling below the system's requirements. Signs that a pump is wearing out will be a slowing of cylinder action because of a reduced flow of fluid, and a loss of system pressure.

Three basic types of pumps are used in hydraulic systems: gear, vane, and piston pumps (Figure 3-22). Each type has characteristics that make it suitable for a certain system.



GEAR

VANE

PISTON

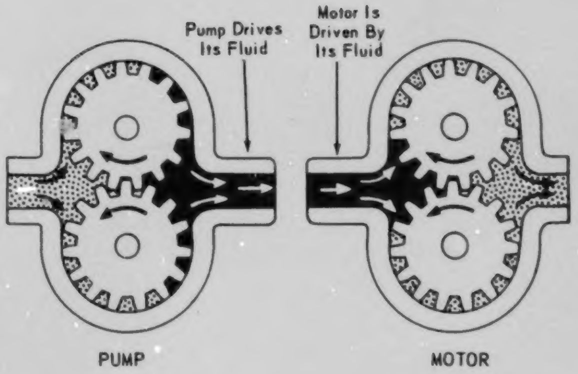
(3-22) Three Types of Hydraulic Pumps

Courtesy of John Deere Ltd.

HYDRAULIC MOTORS

In the discussion of a basic hydraulic system, a pump supplied hydraulic pressure and flow to drive a cylinder. A pump can also be used to drive a hydraulic motor.

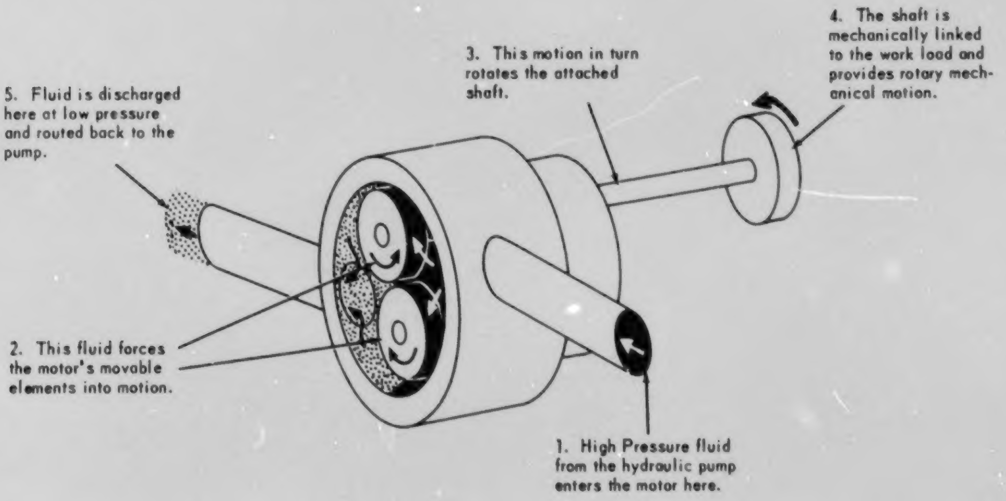
A hydraulic motor works in reverse to a hydraulic pump: the pump drives its fluid while the motor is driven by its fluid (Figure 3-23). A pump draws in fluid and pushes it out, converting mechanical force into fluid force. Conversely, a motor has fluid forced into and out of it, and in the process fluid force is converted into mechanical work force.


Pump Drives Its Fluid
Motor Is Driven By Its Fluid
PUMP
MOTOR

(3-23) Hydraulic Pump and Motor Compared

Courtesy of John Deere Ltd.

The basic operation of a hydraulic motor is explained in Figure 3-24.


5. Fluid is discharged here at low pressure and routed back to the pump.
3. This motion in turn rotates the attached shaft.
4. The shaft is mechanically linked to the work load and provides rotary mechanical motion.
2. This fluid forces the motor's movable elements into motion.
1. High Pressure fluid from the hydraulic pump enters the motor here.

(3-24) Basic Operation of Hydraulic Motor

Courtesy of John Deere Ltd.

Like hydraulic pumps, there are gear, vane and piston hydraulic motors. The motors are rated by motor horsepower, a combination of force and speed. Horsepower = Force × Speed.

CONTROL VALVES

Valves are the controls of the hydraulic system. They regulate the pressure, direction, and volume of oil flow in the hydraulic circuit.

Valves can be divided into three major types:

1. Pressure Control Valves
2. Directional Control Valves
3. Volume Control Valves

Figure 3-25 shows the basic operation of the three types of valves.

Pressure Control Valves — are used to limit or reduce pressure, unload a pump, or set the pressure at which oil enters a circuit. Pressure control valves include relief valves, pressure reducing valves, pressure sequence valves, and unloading valves.

Directional Control Valves — control the direction of oil flow within a hydraulic system. They include check valves, spool valves, and rotary valves.

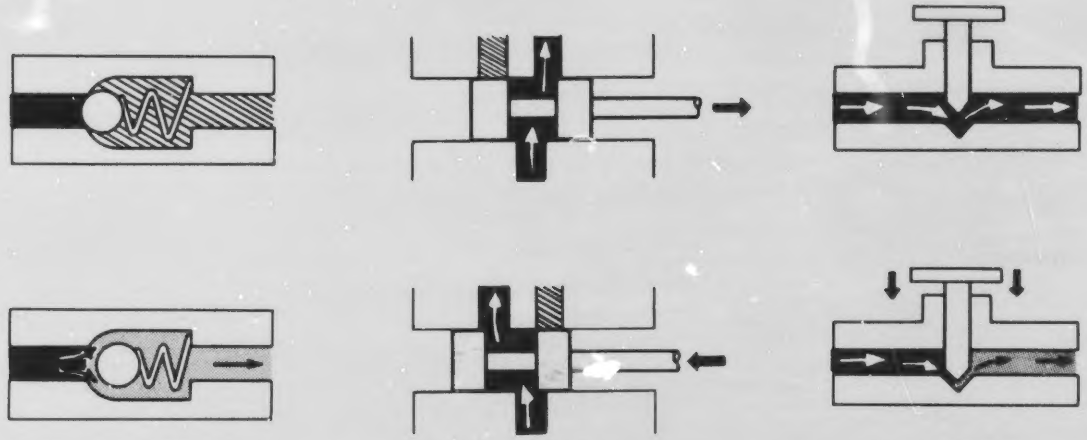
Volume Control Valves — regulate the volume of oil flow, usually by throttling or diverting it. They include compensated and non-compensated flow control valves and flow divider valves.

Some valves are variations on the three main types. For example, many volume control valves use a built-in pressure control valve.

Valves can be controlled in several ways: manually, hydraulically, electrically, or pneumatically (compressed gas). In some modern systems, the entire sequence of valve operation for a complex machine can be made automatically.

Hydraulic valves may or may not be adjustable, depending on their location and purpose.

Generally speaking if the hydraulic system is kept clean, valves will give little trouble.



PRESSURE CONTROL

DIRECTIONAL CONTROL

VOLUME CONTROL

(3-25) The Three Types of Valves

Courtesy of John Deere Ltd.

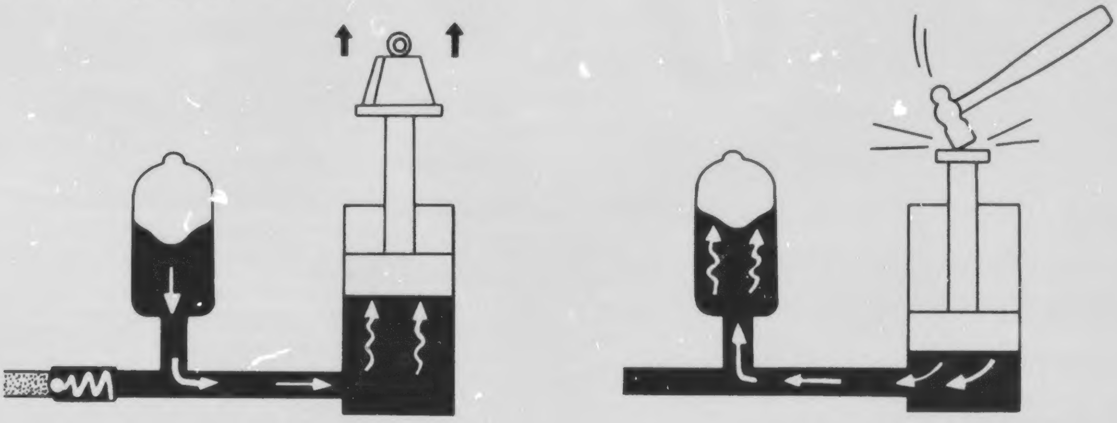
HYDRAULICS ACCUMULATORS

A hydraulic accumulator is basically a cylinder with a piston that is opposed by a spring or compressed gas. Fluid from the hydraulic system enters the cylinder and pushes against the piston. The piston in turn pushes against the spring or the compressed gas. Thus the piston, with the compressed spring or the compressed gas exerting a force against it, becomes a source of potential engergy. This potential energy could be used, for example, in a brake system to apply the brakes if, for some reason, the hydraulic system pressure failed.

Besides storing energy for the hydraulic system, accumulators can absorb shocks, build pressure gradually, and maintain a constant pressure (Figure 3-26).

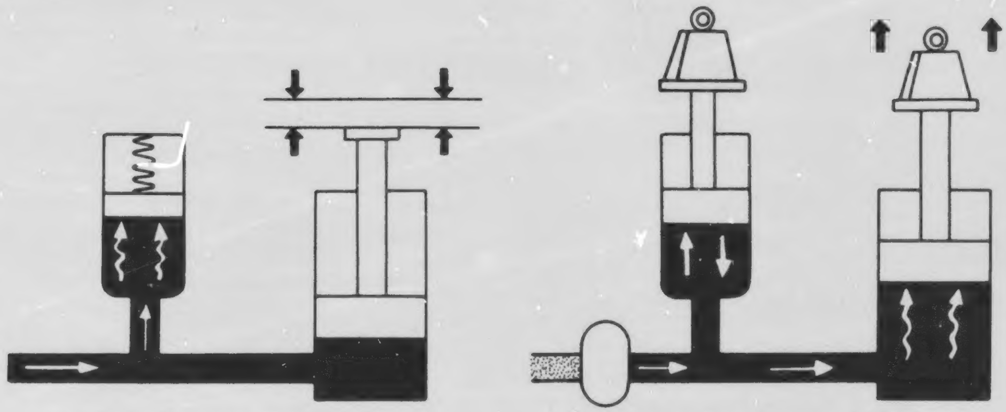
While most accumulators can do any of these four functions, their use in a system is usually limited to one of them.

Accumulators which **Store Energy** are often used as "boosters" for systems with fixed displacement pumps. The accumulator stores pressure oil during slack periods and feeds it back into the system during peak periods of oil usage. The pump recharges the accumulator after each peak. Sometimes the accumulator is used as a protection against failure of the oil supply, for example, on power brakes on larger machines. If the system oil supply fails, the accumulator feeds in several charges of oil for use in emergency braking.



STORE ENERGY

ABSORB SHOCKS



BUILD PRESSURE GRADUALLY

MAINTAIN CONSTANT PRESSURE

(3-26)

Courtesy of John Deere Ltd.

Accumulators which **Absorb Shocks** take in excess oil during peak pressures and let it out again after the surge is past. This reduces vibrations and noise in the system. The accumulator may also smooth out operation during pressure delays, as when a variable displacement pump goes into stroke. By discharging at this moment, the accumulator takes up the slack.

Accumulators which **Build Pressure Gradually** are used to soften the working stroke of a piston against a fixed load, as in a hydraulic press. By absorbing some of the rising oil pressure the accumulator slows down the stroke.

Accumulators which **Maintain Constant Pressure** are always weight-loaded which places a fixed force on the oil in a closed circuit. If the volume of oil changes from leakage or from heat expansion or contraction, this accumulator keeps the same gravity pressure on the system.

Pneumatic or Gas Loaded are the most common types of accumulators used on mobile hydraulic systems. Gas loaded accumulators use the principle that gas will compress while fluid will not. In an accumulator gas and oil occupy the same container, but are usually separated by a diaphram or a piston. The cylinder is charged with an inert gas, dry nitrogen (not oxygen), to a specified precharge. When the oil opposes the compressed gas, the gas will compress further providing a static pressure over the entire system. The compressed gas also acts as a cushion for the system.

Pressurized systems can be dangerous. Always bleed down a system that uses a gas charged accumulator, before working on it. To discharge the accumulator, shut down the engine and move **all** the hydraulic controls through all their operating positions.

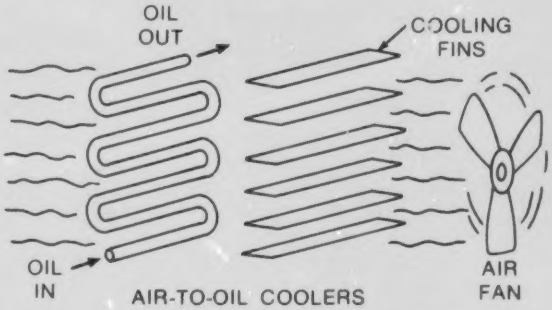
OIL COOLERS

On modern high-pressure hydraulic systems, cooling the oil can be a problem. Often normal circulation of the oil in the system will not provide adequate cooling. Thus the need for oil coolers.

The purpose of the oil cooler is to keep the oil at an ideal operating temperature, 180° to 200°F. If under extreme conditions the cooler cannot keep the oil temperature within this range it must at least keep the oil under 250°F. Beyond 250°F a chemical change takes place in the oil, causing it to oxidize at a high rate.

TYPES OF COOLERS

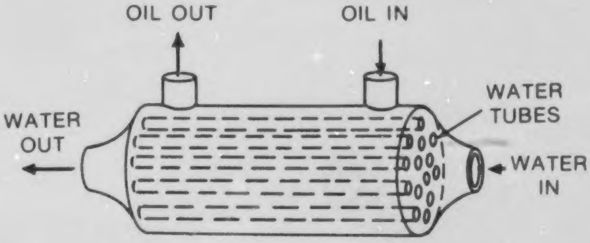
Air-to-Oil Coolers use moving air to dissipate heat from the oil (Figure 3-27). On mobile machines, the cooling system (radiator) fan may supply the air blast. The cooler has fins which direct the air over long coils of oil tubes which expose more oil to the air. The cooler may also have a tank to store a reserve of cooled oil. A bypass valve is also sometimes used as a safety valve in case the cooler oil tubes become clogged.



AIR-TO-OIL COOLERS

(3-27) Courtesy of John Deere Ltd

Water-to-Oil Coolers use moving water to carry off heat from the oil (Figure 3-28). The water flows through many tubes and the oil circulates around the cooling tubes as shown. On mobile machines, water from the engine radiator is often used for cooling.



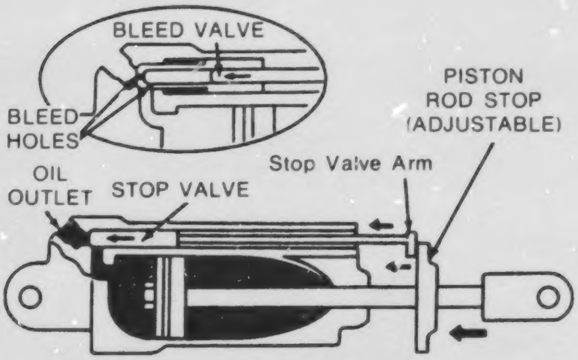
WATER-TO-OIL COOLER

(3-28) Courtesy of John Deere Ltd

Air-to-oil coolers such as the one shown are usually mounted in front of the engine radiator, making use of the fan's air blast. Other coolers can be mounted in a variety of locations, but are usually placed near the reservoir or the engine cooling fan.

HYDRAULIC CYLINDERS

A double acting hydraulic cylinder is shown in Figure 3-29. Cylinders will vary in their diameter and stroke length.



(3-29) PISTON-TYPE CYLINDER

Courtesy of John Deere Ltd

Some cylinders have a safeguard built into them to prevent the piston from bottoming out with a damaging force. As the piston nears either end of its stroke, passages in the cylinder allow the oil to bypass the piston, thus taking away the pressure that would force the piston into the ends of the cylinder.

Packing glands are used to seal the cylinder at the point where the rod extends from the cylinder. Some of these packings can be adjusted to prevent oil leaking from the cylinder. Adjusting and replacing rod packings and seals are covered in the discussion of bearings and seals in Frames, Suspensions Running Gear and Attachments.

QUESTIONS — HYDRAULIC THEORY

1. Give at least five uses of hydraulics on Heavy Duty Equipment.

2. Give at least two advantages and disadvantages of a hydraulic system.

3. One of the basic principles which makes hydraulic action almost instantaneous is that liquid is:

   (a) Compressible; transmits power by compressing.

   (b) Non-compressible; transmits applied pressure in all directions throughout the liquid.

   (c) Full of fluid.

   (d) Frictionless and flows quickly.

4. The pressure (P.S.I.) in a hydraulic system is determined by:

   (a) Multiplying the force × area = F × A

   (b) Dividing the area by the force $=\frac{A}{F}$

   (c) Dividing the force by the pressure $=\frac{F}{P}$

   (d) Dividing the force by the area $=\frac{F}{A}$

5. Briefly explain the terms velocity and flow rate.

6. The term viscosity is the measure of __________ in hydraulic oils.

   Viscosity Index reflects the way viscosity changes with __________.

   With respect to additives the most desirable oils for hydraulic service contain high amounts of __________ __________.

7. What are the five basic parts required to makeup a hydraulic system?

8. The function of filters in a hydraulic system is to catch and hold _______ __________ that get into the oil.

9. Pumps used in hydraulic systems are referred to as:

   (a) Direct displacement pump.

   (b) Indirect displacement pumps.

   (c) Positive pressure pumps.

   (d) Positive displacement pumps.

10. Hydraulic pump output is rated in terms of:

    (a) Pressure and speed.

    (b) Gallonage at a specific R.P.M. and pressure.

    (c) Horsepower.

    (d) Gallonage.

11. What is the effect on the velocity of the flow of oil if the line size is decreased?

12. If a smaller line size was mistakenly put on a hydraulic system that operated a hydraulic implement, what would the effect be on the implement?

13. Basically, what is the difference between a hydraulic pump and a hydraulic motor?

14. Name the three basic types of valves found in a hydraulic system.

15. An accumulator may be used in a system to:

    (a) Store energy.

    (b) Absorb energy.

    (c) Maintain a constant pressure.

    (d) All of the above.

16. The purpose of an oil cooler in a hydraulic system is to:

    (a) Keep the oil as cold as possible.

    (b) Cool the oil and act as additional reservoir.

    (c) Keep the oil at an ideal operating temperature.

    (d) Filter and cool the oil.

17. There are two basic types of cylinders used in a hydraulic system:

    __________ acting and __________ acting.

    Briefly explain the difference.

18. If you increase the size of the piston in a basic hydraulic system, what is the effect on the output force of the piston? On the speed of the piston?

19. What advantage does a small hydraulic cylinder have over a larger one?

20. What is the effect on a hydraulic system when the pump becomes worn?

    (a) pump heats up.
    (b) gallons per minute output is decreased.
    (c) the hydraulically operated working implement will slow down.
    (d) both (b) and (c)

21. What is the function of an accumulator in a hydraulic brake system?

DAILY-ROUTINE AND SCHEDULED MAINTENANCE ON HYDRAULIC SYSTEMS

A daily-routine check on a hydraulic system is done as part of the walk around inspection of the machine and should include:

1. A careful inspection of the components and hoses for leaks and signs of damage.
2. A Reservoir oil level check: some machines use a "dipstick" and some a sight glass. The machine must be level for this check.

Repair any leaking or damaged hoses and fittings right away. Minor repairs, if not attended to can turn into major repairs and costly down time.

Scheduled maintenance procedures will be outlined in the service manual. These procedures will include:

- — Changing filters
- — Cleaning screens
- — Cleaning breathers
- — Adding or changing oil
- — Replacing damaged hoses and fittings
- — Checking hydraulic rams for scores or burrs

Scheduled maintenance on a hydraulic system may also include flushing the system. Flushing is described near the end of this section.

When servicing hydraulic systems, practice the following habits of safety, cleanliness and good workmanship.

SAFETY PRACTICES ON A HYDRAULIC SYSTEM

1. Shut down the engine.
2. Unless stated otherwise in the service manual, lower all implements to the ground, and level them if necessary.
3. Apply the parking brake and chalk the wheels on wheeled vehicles.
4. Bleed off pressure in the system so that you don't get showered with hot oil.

   Pressure in a hydraulic system comes from three sources:

   (a) Resistance to pump flow.

   (b) Accumulators.

   (c) Hydraulic cylinder: The weight of an implement pushing against oil trapped in the cylinder(s) creates a pressure within the oil.

To release the pressure:

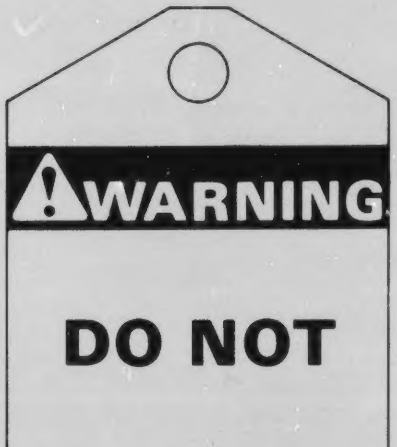
(a) With the engine off, move all of the hydraulic controls through all of their operating positions.

(b) Loosen the reservoir cap a few turns or open the vent screw. Never open the filler cap of a pressurized reservoir without first releasing the pressure in the reservoir.

SAFETY PRACTICES FOR A SCHEDULED MAINTENANCE CHECK

All of the above, plus:

1. Install a steering safety lock on articulated machines.
2. If the machine has a power shift transmission, apply the shift safety lock.
3. If the machine has a master switch, turn it off and remove the key.
4. Hang a Do-Not-Operate tag on the controls (Figure 3-30).
5. If implements have to be serviced in the raised position, use only the approved blocking to support it.



(3-30)

Courtesy of J1 Case

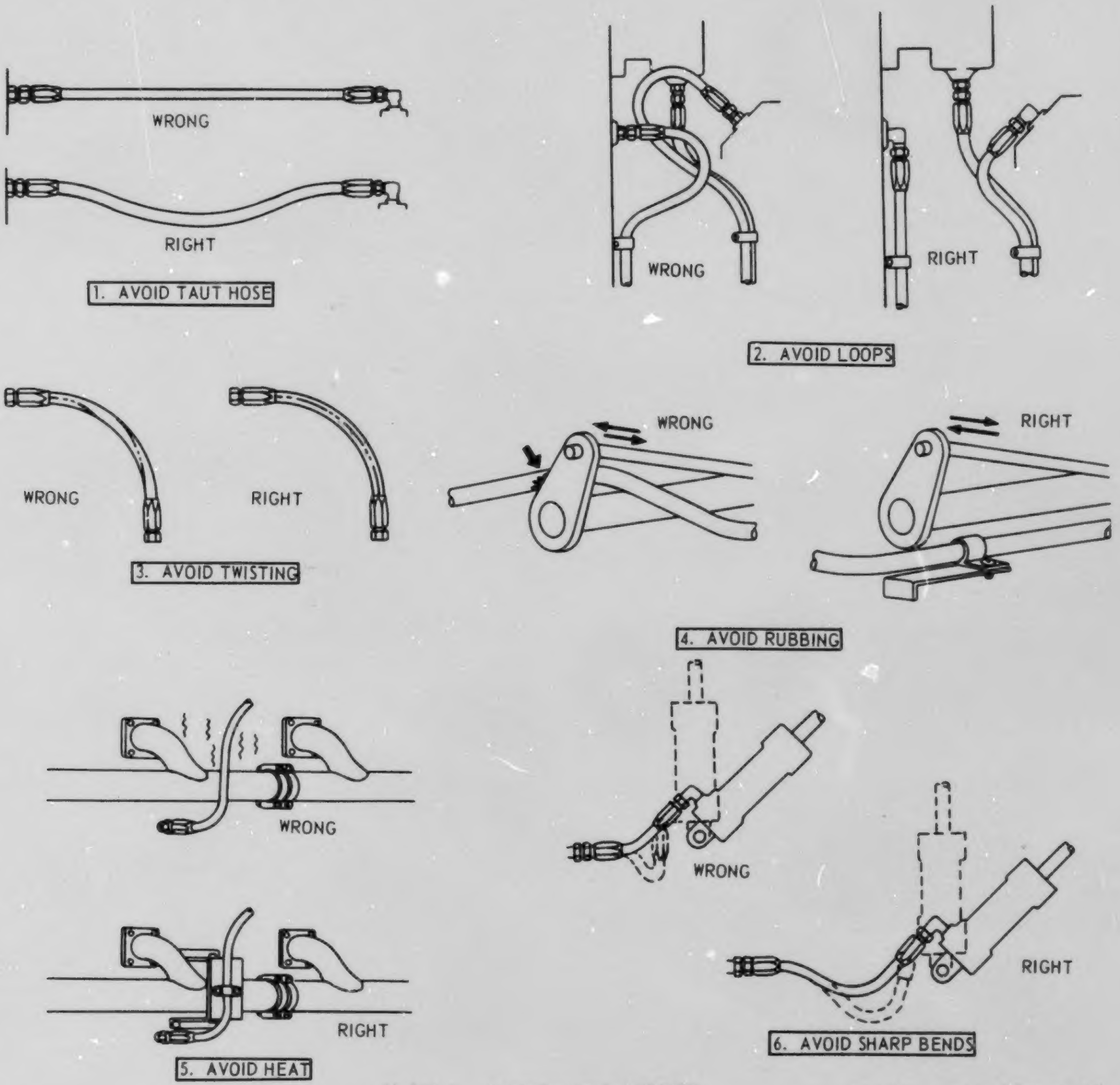
It is absolutely essential that hydraulic systems be kept clean. Practice the following habits of cleanliness when working on or around hydraulic systems.

1. Clean around filler caps before removing them.
2. Wash off filter housings, hose fittings and lines, before removing them.
3. Use only clean containers, funnels, cans, etc. to transfer oil.
4. Always install cap plugs on disconnected lines and fittings.
5. Observe good storage practices for hydraulic oil.
6. When changing a hydraulic pump, clean the complete area around the pump before disconnecting it.

Good work practices to follow when removing and installing hydraulic hoses.

Many hose failures can be related to improper installation such as:

1. **Improper hose length** — When a hose is under pressure it expands. Hoses which are too short have no room for expansion, and therefore will pull apart. Hoses which are too long can be exposed to hazards from moving parts.
2. **Rubbing** — Rubbing will chafe the outer cover and soon weaken the hose to a point of failure. Secure the hose by clamping to avoid it coming into contact with moving parts.
3. **Heat** — Route all hoses away from exhaust pipes and cooling system pipes because heat will rapidly deteriorate hoses.
4. **Twisting** — Hoses should lie naturally, without any twist. You can tell if a hose is twisted by looking at the laylines on the hose. Twisting can occur when a hose is connected to two moving parts which have relative movement between one another. To deter such twisting, split the movement in the hose by supporting the hose at its mid point. Use a proper fitting clamp: don't use one that is too large. Twisting can also occur if a hose is installed without using two wrenches to tighten the fittings, one wrench to hold the hose, and one to tighten the swivel connector.
5. **Wrong hose selection** — Wrong size or wrong pressure rating can cause failure. Refer to the hose selection in Block 1.


WRONG
RIGHT
1. AVOID TAUT HOSE
WRONG
RIGHT
2. AVOID LOOPS
WRONG
RIGHT
3. AVOID TWISTING
WRONG
RIGHT
4. AVOID RUBBING
WRONG
RIGHT
5. AVOID HEAT
WRONG
RIGHT
6. AVOID SHARP BENDS

(3-31) INSTALLING HOSES Courtesy of John Deere Ltd.

When removing hydraulic hoses:

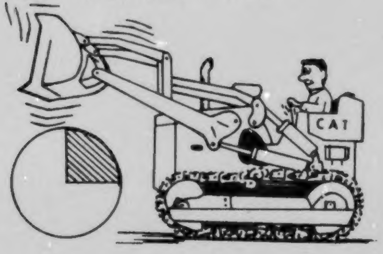
1. Probably the most important point when removing a hydraulic hose is to know what you are disconnecting so that you know what pressure or oil flow to expect when it's taken off. For example, removing an intake line from a pump on a system with a reservoir mounted high with no shut off could result in a pretty big puddle of oil on the floor.
2. If a number of hoses are being disconnected in the same area, tag the hoses so you know which is which when reconnecting them.
3. As was said for installation, should the swivel fitting be tight, use two wrenches to loosen or tighten fittings to avoid twisting the hose.

FLUSHING PROCEDURES

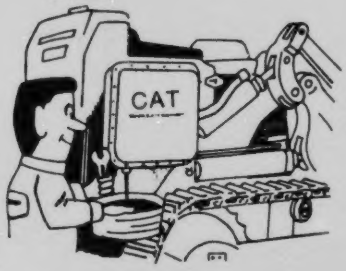
Occasionally a hydraulic system may have to be flushed to remove build up of contaminants. Flushing procedures will be found in the service manual; a typical example is shown on the following page.

GENERAL FLUSHING METHOD 1

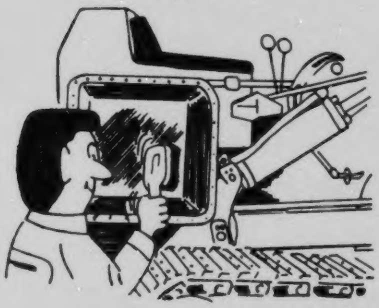
1 **CYCLE THE MACHINE**
FOR 15 MINUTES TO STIR UP ANY DIRT PARTICLES IN THE HYDRAULIC SYSTEM.



2 **DRAIN THE TANK**
RAISE THE BUCKET, EXTEND ALL CYLINDER RODS, DRAIN THE HYDRAULIC OIL. THEN ALLOW BUCKET TO LOWER BY GRAVITY FOR MAXIMUM DRAIN.

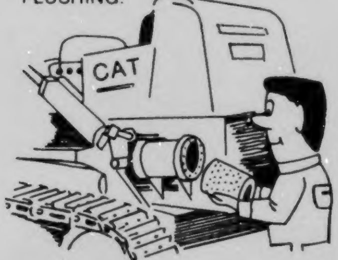


3 **CLEAN TANK**
REMOVE BOTTOM OR SIDE IF POSSIBLE AND CLEAN THOROUGHLY.

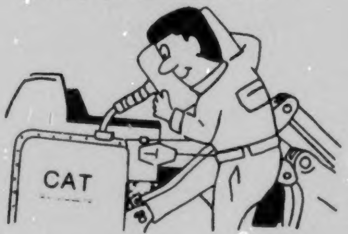


If a hydraulic system is very badly contaminated, as would occur when a pump failed and caused a large accumulation of metal particles in the oil, flushing would not adequately clean the system. In this case all the components would have to be completely disassembled and cleaned. The job would be a major one and would require the help of a journeyman.

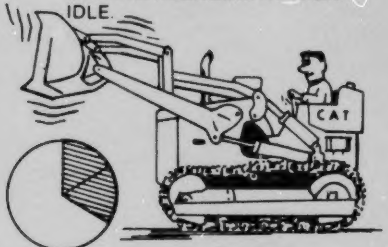
4 **CHANGE FILTER ELEMENT**
CHANGE ALL ELEMENTS IN THE SYSTEM. INSTALL 10 MICRON ELEMENTS DURING FLUSHING.



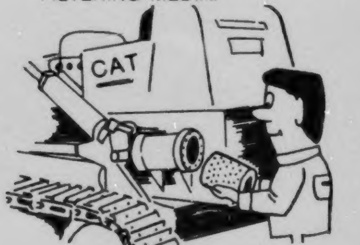
5 **REFILL TANK**
WITH RECOMMENDED GRADE OF SERIES 3 OIL.



6 **FLUSH SYSTEM**
SLOWLY CYCLE EACH CYLINDER OR PAIR OF CYLINDERS FOR 10 MINUTES EACH WITH ENGINE AT HIGH IDLE.



7 **REPLACE FILTER ELEMENT**
CHANGE ALL ELEMENTS IN THE SYSTEM. INSTALL ELEMENTS WITH PROPER FILTERING MEDIA.



(3-32)

Courtesy of Caterpillar Tractor Co.

QUESTIONS — MAINTENANCE OF HYDRAULIC SYSTEMS

1. List the things that would be done to a hydraulic system during scheduled maintenance.
2. Before doing a daily maintenance check on a machine's hydraulic system, what safety practices must be carried out?
3. Premature hose failure can occur after installation because of:
    (a) Improper length and twisted.
    (b) Being too close to moving parts.
    (c) Too near a heat source.
    (d) All of the above.
4. What is the most important thing to know when disconnecting a hydraulic hose? Explain why.

ANSWERS — HYDRAULIC THEORY

1.
    1. brakes
    2. steering
    3. working attachments
    4. transmissions
    5. propel
2. Advantages:
    1. Simple in construction
    2. Gives a wide range of speed and force.
    3. System is protected against damage by relief valves.

    Disadvantages:
    1. Subject to leaks from high pressure, shock loading and heat.
    2. Heat from friction causes some loss of efficiency.
    3. Need for cleanliness, must be kept clean.
3. (b) Non-compressible; transmits applied pressure in all directions throughout the liquid.
4. (d) Dividing the force by the area $= \frac{F}{A}$
5.
    1. Velocity is the average speed of a fluid past a given point.
    2. Flow rate is the measure of the volume of fluid that passes a point in a given time.
6. fluidity

    temperature

    anti-wearing compounding
7.
    1. a reservoir
    2. a pump
    3. a relief valve
    4. a control valve
    5. a cylinder
8. insoluble contaminants
9. (d) positive displacement pumps
10. (b) gallonage at a specific r.p.m. and pressure
11. If the line size is decreased, the velocity of the fluid will increase. When fluid travels at higher speed, greater friction and thus heat is created in the lines.
12. With the smaller lines, the velocity of the fluid will increase, but it won't increase enough to maintain the flow rate. With less flow, the implement will operate more slowly.
13. A pump drives the fluid while a motor is driven by the fluid.
14. pressure control valve

    volume control valve

    directional control valve
15. (d) All of the above.
16. (c) Keep the oil at an ideal operating temperature.
17. . . . single . . . double

    The single acting cylinder can be powered only in one direction (in extension), whereas the double acting cylinder can be powered in two directions (extension and retraction).
18. The output force will be greater because there will be a greater area for the pressure to act against. The speed of the piston, however, will be decreased.
19. The smaller cylinder will act with greater speed.
20. (d) both (b) and (c)
21. An accumulator is a safety device in a hydraulic brake system which supplies enough fluid to stop the vehicle should the system fail.

ANSWERS — MAINTENANCE OF HYDRAULIC SYSTEMS

1. changing filters

   cleaning screens

   cleaning breathers

   adding or changing oil

   Replacing damaged hoses and fittings and repairing leaks. Checking hydraulic rams for scores or burns and leaks. Sometimes flushing.

2. 1. Shut off engine.
   2. Lower all implements to the ground and level them.
   3. Apply parking brake or block wheels.
   4. Neutralize or bleed off all pressure by operating all controls and open vent on reservoir.

3. (d) All of the above.

4. Know what you are disconnecting. A head of oil and/or pressure in the line when disconnected could prove messy or even harmful.

TASKS — HYDRAULICS

PREVENTIVE MAINTENANCE SERVICE ON HYDRAULIC SYSTEMS

SAFETY

Practice safety when working on hydraulic systems by:

1. Installing safety bars on raised working attachments.
2. Bleeding down the pressure before disconnecting lines, removing components or opening the reservoir.
3. Installing steering safety rod on articulated machines.

DAILY AND ROUTINE MAINTENANCE CHECK

1. On a loader backhoe or similar hydraulically operated machine: inspect the complete hydraulic system for indications of failure such as leaks at hoses, at fittings, at cylinder rod seals and pump seals, for damaged or chafed hoses or damaged piston rods, and for loose cylinder or pivot point pins. Report any suspected problems to a journeyman.
2. Vent the reservoir, check the oil level and fill if low.

SCHEDULED MAINTENANCE

On a loader, backhoe or similar hydraulically operated machine, after consulting the service manual:

1. Drain the hydraulic system.
2. Remove and clean screens, install new filters, and refill the system with the correct type and amount of oil.
3. Start the machine, activate all controls, and check to ensure there are no oil leaks. Stop the machine and recheck the oil level.

SERVICE REPAIR

On a loader, backhoe or similar hydraulically operated machine:

1. Completely flush the hydraulic system, following flushing procedures outlined in the service manual.
2. Remove and clean the screens, install new filters, refill the system with the correct type and amount of oil.
3. Start the engine, activate all controls, and check to ensure there are no oil leaks. Stops the machine and recheck the oil level.

BLOCK

4

Brakes

BRAKE OPERATION

The function of brakes is to stop or slow a vehicle's rate of travel. Brakes operate on a principle of friction: a fixed, non-turning surface (brake lining) is pressed into contact with the turning wheels (the brake drum or disc) causing a resistance to the wheels' motion which slows and eventually stops the wheels. In this frictional process, energy of motion from the wheels is turned into heat energy in both the linings and brake drums or discs. The transfer of motion energy to heat energy is in accordance with the Law of Conservation of Energy which says that energy cannot be created or destroyed, only transformed from one form to another. The linings and drums or discs must quickly absorb and dissipate the heat, in order that braking action continue over the time it takes to stop the vehicle.

BASIC FRICTION THEORY RELATED TO BRAKES

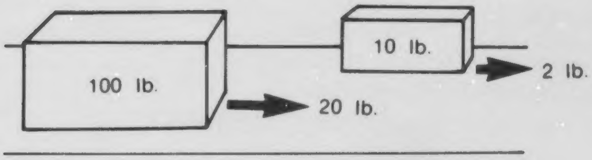
Friction is the force that resists the movement of one surface over another. The strength of frictional force between two surfaces is called the coefficient of friction. Coefficient of friction depends on the types of materials in contact, the condition of their surfaces, the temperatures of the surfaces, and the contact speed.

In mathematical terms the coefficient of friction is the ratio of the weight of a body to the amount of force required to slide it over a surface. For example, if it takes a 60 pound force to slide a 100 pound block of rubber over a concrete floor, the coefficient of friction of rubber over concrete would be:

$$\frac{60}{100} = .6 \text{ C.O.F.}$$

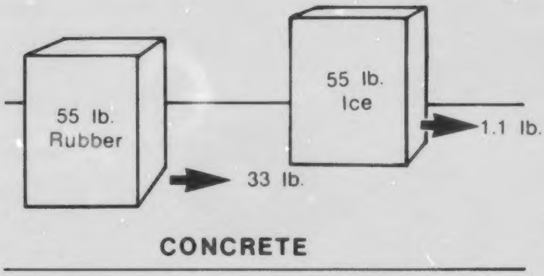
Figures 4-1 and 4-2 illustrate two points about coefficients of friction.

1. The force needed to pull a material across a surface is proportional to its weight.



(4-1)

2. Rubber has a much higher coefficient of friction than ice and therefore requires a much greater force to be pulled across concrete.

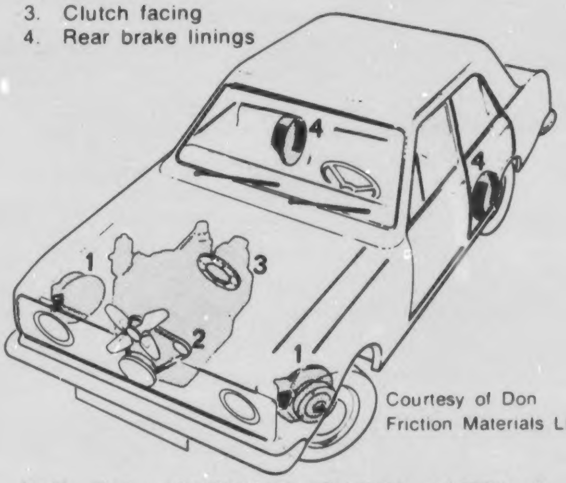


(4-2)

Thinking about point 2 you can see that by using different brake lining materials, the coefficient of friction of the brake can be varied. In other words, brake performance can be altered by changing the brake lining materials. For example, a lining with a high coefficient of friction will slow a vehicle with less application pressure than will a lining with a low C.O.F. Brake linings are often made of a composition of materials which will suit the braking requirements of a certain vehicle. Some brakes will use both a high friction lining and a low friction lining on two shoes in the same brake; this system balances the braking effort between the two shoes.

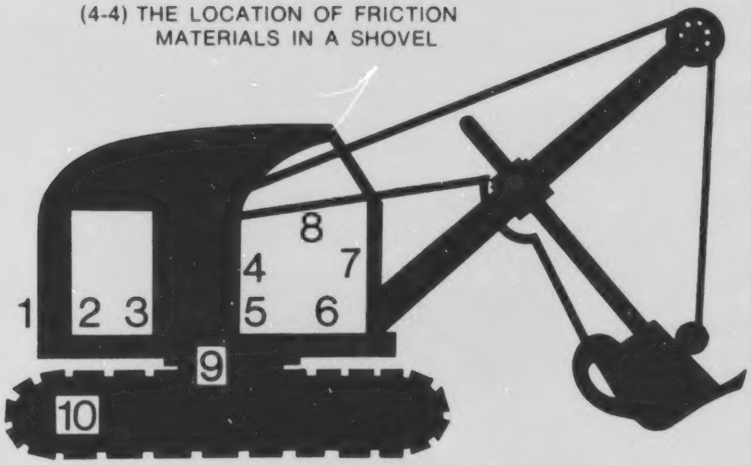
While discussing brake friction materials, it's worth noting the other friction materials in vehicles. Figures 4-3 and 4-4 illustrate the friction materials in a family car and in a shovel.

1. Front disc brakes (pads)
2. Fan belt
3. Clutch facing
4. Rear brake linings



Courtesy of Don Friction Materials Ltd

(4-3) THE LOCATION OF FRICTION MATERIALS IN A CAR.



(4-4) THE LOCATION OF FRICTION MATERIALS IN A SHOVEL

① *Engine Clutch*
② *Hoist Clutch* *Hoist Brakes*
③ *Hoist Clutch* *Hoist Brakes*
④ *Crowd Brake*
⑤ *Retract*
⑥ *Crowd Clutch*
⑦ *Swing Clutch*
⑧ *Tripper Clutch*
⑨ *Swing Brake*
⑩ *Travel Brakes*

Courtesy of Don Friction Materials Ltd.

FACTS ON BRAKING

1. To give an example of the tremendous forces involved in braking a commercial vehicle consider the following:

   The average truck having an engine capable of developing 100 horsepower requires about one minute to accelerate to a speed of 60 miles per hour, whereas the same vehicle should be capable of easily stopping from 60 miles per hour in not more than six seconds. Ignoring the unknown quantities such as rolling friction and wind resistance which admittedly play a part in all stops, the brakes must develop the same energy in six seconds as the engine develops in 60 seconds. In other words, the brakes do the same amount of work as the engine in one-tenth the time. This means that they must develop approximately 1,000 horsepower during the stop.

2. Braking power is directly proportional to vehicle weight. For example a 10,000 pound vehicle would need twice as much braking power to stop it as would a 5,000 pound vehicle travelling at the same speed.

3. Speed has an even greater effect on braking power than does weight. A vehicle will need 5 times as much stopping power at 70 km/h, and 9 times as much at 100 km/h as it needs at 35 km/h.

4. Other factors affect braking power such as brake shoe leverage, number of tires and road surface deceleration; these will be discussed in a later course.

BRAKE CAPACITY

Brakes are classified according to their stopping power or horsepower absorption capacity. Brakes have a limit to the amount of horsepower they can absorb without damage to themselves other than normal wear on the brake linings and drums. No control, however, is built into brakes as to how much horsepower they will absorb. If called on to absorb more horsepower than they are built for, brakes will do so and destroy themselves in the process. It is very important, therefore, when brakes are designed for a vehicle that they be of adequate capacity to absorb the horsepower that a vehicle of a given engine size, weight and travelling speed will produce.

TYPES OF BRAKE SYSTEMS

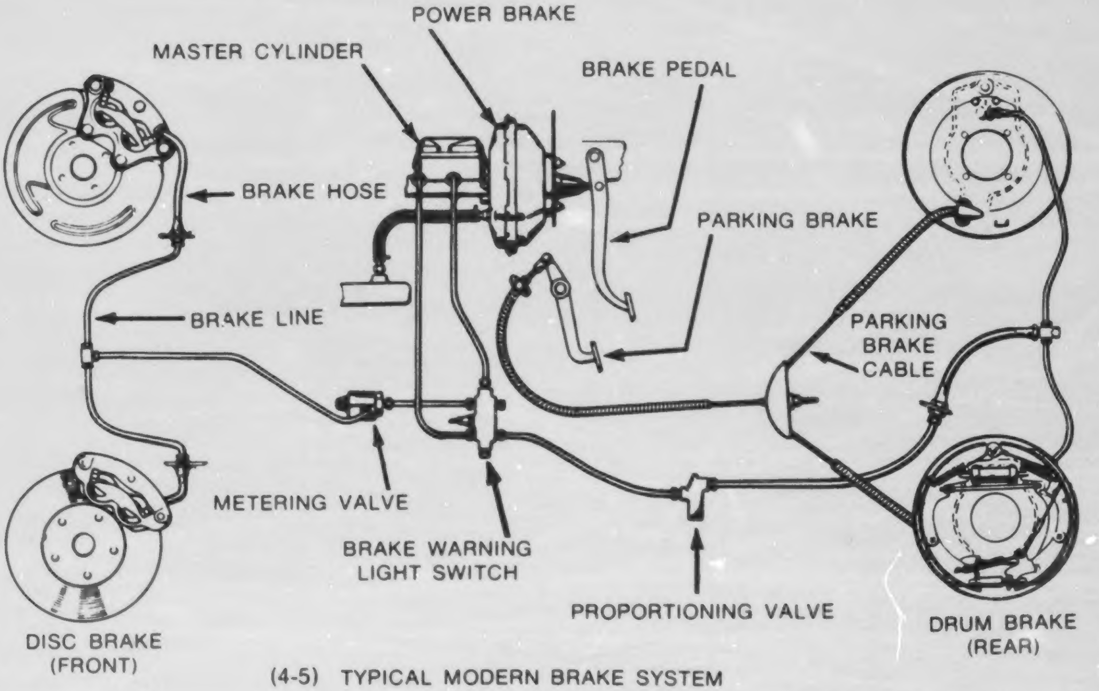
Generally a vehicle or machine will be equipped with two types of brakes:

1. parking brakes
2. service brakes

Parking Brakes secure a vehicle when stopped. Parking brakes can be used in an emergency should the service brakes fail, but if they are applied when the vehicle is travelling fast or is heavily loaded, they will burn out. Parking brakes will be looked at in greater detail later on in this section.

Service Brakes slow or stop the vehicle. They are designed to have a braking capacity sufficient to stop the vehicle when travelling within a speed and load limit. If the speed and load limit are exceeded, service brakes will not perform satisfactorily.

Figure 4-5 shows a typical automobile or light truck brake system. Note that this vehicle has disc brakes on the front and drum brakes on the rear.


POWER BRAKE
MASTER CYLINDER
BRAKE PEDAL
BRAKE HOSE
PARKING BRAKE
BRAKE LINE
PARKING BRAKE CABLE
METERING VALVE
BRAKE WARNING LIGHT SWITCH
PROPORTIONING VALVE
DRUM BRAKE (REAR)
DISC BRAKE (FRONT)

(4-5) TYPICAL MODERN BRAKE SYSTEM

Courtesy of Bendix Corporation

SERVICE BRAKES

Three types of service brakes are used on heavy duty vehicles:

1. Standard Hydraulic brakes
2. Power-assisted hydraulic brakes
    - Vacuum-assisted
    - Air-over-oil
    - Oil-over-oil
3. Full Air-Brakes

STANDARD HYDRAULIC BRAKES

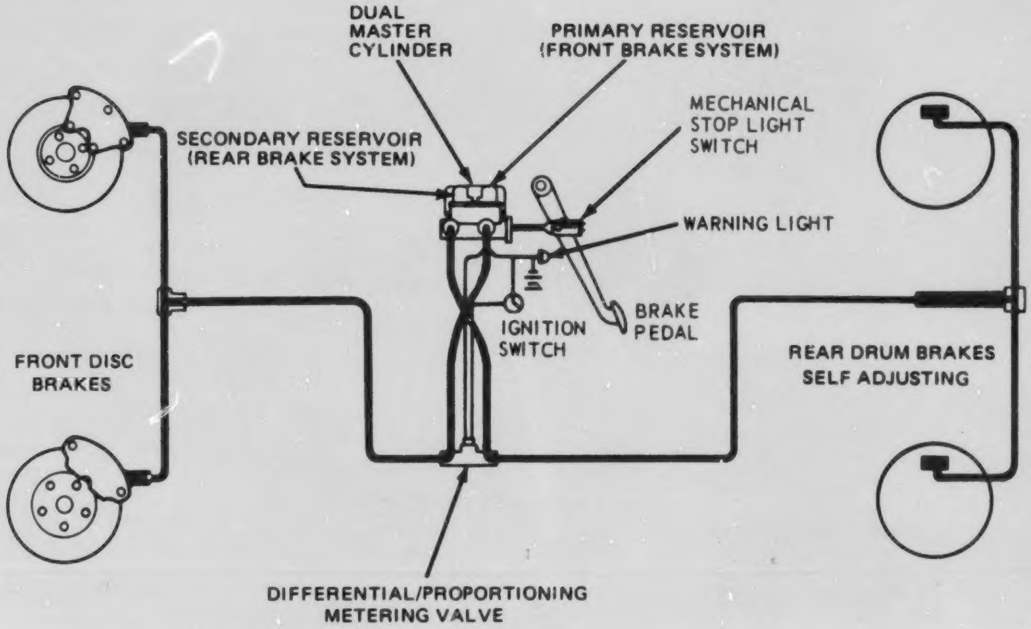
Standard hydraulic brakes are usually found on automobiles and light trucks. They operate on the basic hydraulic principle of transmitting force and motion through a confined fluid.

A standard hydraulic brake system (Figure 4-6) consists of:

1. Master cylinder
2. Wheel cylinders
3. Connecting lines
4. Brake fluid
5. Foundation Brake Assembly
    (a) drum brakes
    (b) disc brakes

In a standard hydraulic brake system a brake pedal is connected to the master cylinder which acts as the pump for the system. Pushing down the brake pedal forces a piston in the master cylinder against confined fluid creating a pressure in the fluid and causing it to flow. The pressurized fluid flows to the hydraulic wheel cylinders mounted at each wheel between the two brake shoes, and the cylinders exert a force on the shoes moving them against the brake drums. When the brake pedal is released, the wheel cylinder pistons are returned by springs to their unapplied position and the fluid is returned to the master cylinder.

Variations on the basic hydraulic brake system use different numbers and arrangements of the components. Some large vehicles have two cylinders per wheel. Trucks use larger cylinders and shoes on the rear wheels since the load is carried on the rear of the truck. Cars and light trucks, on the other hand, use larger cylinders on the front wheels to get increased braking force in the front shoes.


DUAL MASTER CYLINDER
PRIMARY RESERVOIR (FRONT BRAKE SYSTEM)
MECHANICAL STOP LIGHT SWITCH
SECONDARY RESERVOIR (REAR BRAKE SYSTEM)
WARNING LIGHT
BRAKE PEDAL
IGNITION SWITCH
FRONT DISC BRAKES
REAR DRUM BRAKES SELF ADJUSTING
DIFFERENTIAL/PROPORTIONING METERING VALVE
H1985-E

(4-6) HYDRAULIC BRAKE SYSTEM MANUAL BRAKES

Courtesy of Ford Motor Company

FOUNDATION BRAKE

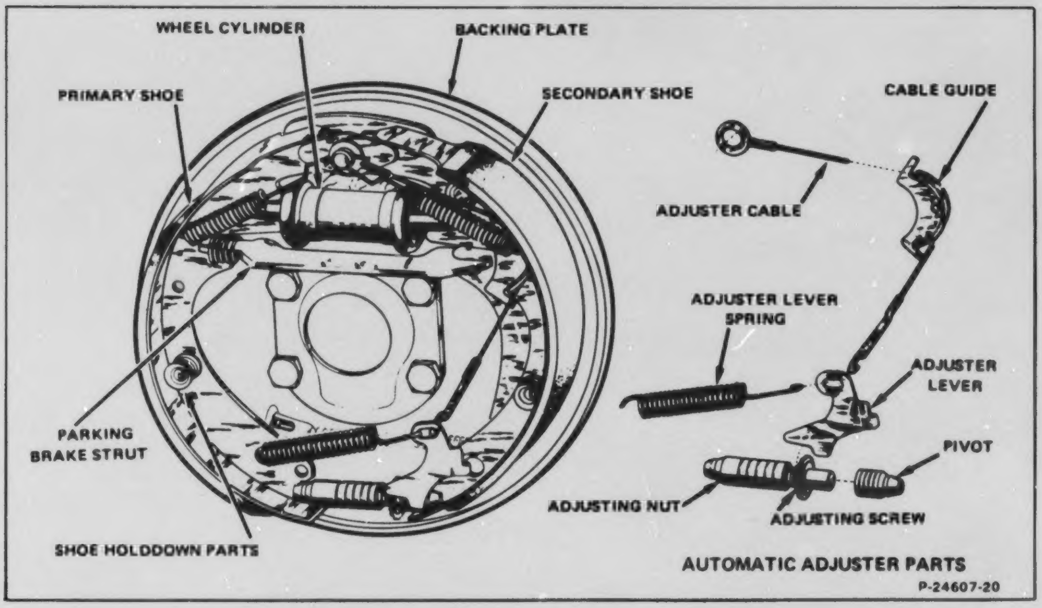
Drum brakes and Disc brakes are the two major types of wheel brakes used on cars, light trucks, and heavy duty vehicles.

DRUM BRAKES

A typical drum brake (Figure 4-7) includes:

- a backing plate or support plate
- two lined brake shoes attached to the backing or support plate
- shoe return springs and shoe holddown parts
- a means of adjusting the shoes to compensate for lining wear
- a drum

The drum brakes on the rear of most passenger cars and light trucks also normally include the additional parts required for parking brakes.


WHEEL CYLINDER
BACKING PLATE
PRIMARY SHOE
SECONDARY SHOE
CABLE GUIDE
ADJUSTER CABLE
ADJUSTER LEVER SPRING
ADJUSTER LEVER
PARKING BRAKE STRUT
PIVOT
ADJUSTING NUT
ADJUSTING SCREW
SHOE HOLDDOWN PARTS
AUTOMATIC ADJUSTER PARTS
P-24607-20

(4-7) TYPICAL DRUM BRAKE (DUO-SERVO TYPE)

Courtesy of Bendix Corporation

There are two main types of drum brakes. Duo-Servo and Non-Servo.

DUO-SERVO BRAKES

The distinguishing feature of a duo-servo drum brake is that a single anchor holds the shoes at their upper ends and the shoes are linked together at the bottom ends by an adjusting screw.

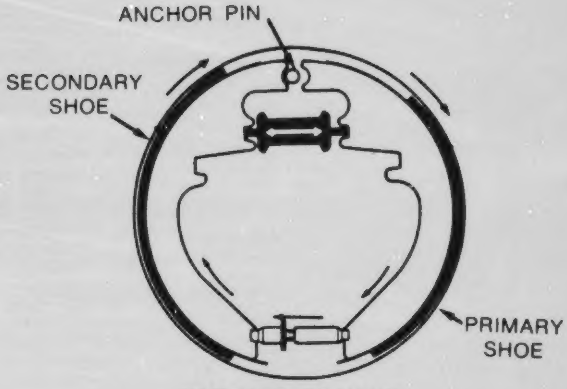
The duo-servo brake obtains its name from the servo principle of brake action which was introduced in the late twenties. During a brake application, each shoe serves the other, and the motion of the vehicle actually helps to apply the brakes.

On a duo-servo brake, the shoe toward the front of the vehicle is called the primary shoe, and the shoe toward the rear is called the secondary shoe. The primary shoe normally has a shorter piece of lining than the secondary.

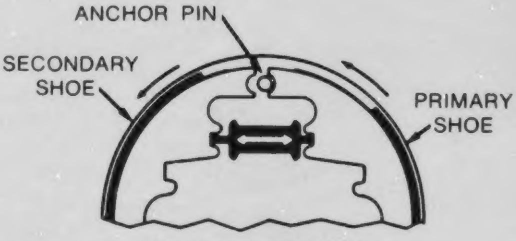
When a vehicle with duo-servo brakes is moving forward and the brakes are applied, the brake shoes are forced outward into the rotating drum. As the linings contact the drum, the primary shoe tends to move in the direction of drum rotation as shown in Figure 4-8. The upper end of the primary shoe is pulled away from the anchor pin. (The shoe has room to move on the pin.) The force produced by the tendency to rotate with the drum is transmitted from the primary shoe through the adjusting screw to the secondary shoe. The result is that the secondary shoe is forced into tighter contact with the drum, and brake efficiency is greatly increased.

During reverse braking, the upper end of the secondary shoe pulls away from the anchor pin and helps to apply the primary shoe.

Duo-Servo brakes often have an automatic adjusting mechanism. The automatic adjuster uses the action of the brake shoes during a reverse brake application to adjust the brakes if an adjustment is required. During a reverse brake application, the secondary shoe tries to rotate with the drum, and the upper end of the shoe moves away from the anchor pin. This places tension on the cable, and the cable pulls the adjuster lever upward. The amount of lever movement depends on how far the secondary shoe moves away from the anchor pin. If the lining has worn enough to require adjustment, the shoe movement will be sufficient to cause the lever to engage the next tooth on the adjusting screw star wheel.



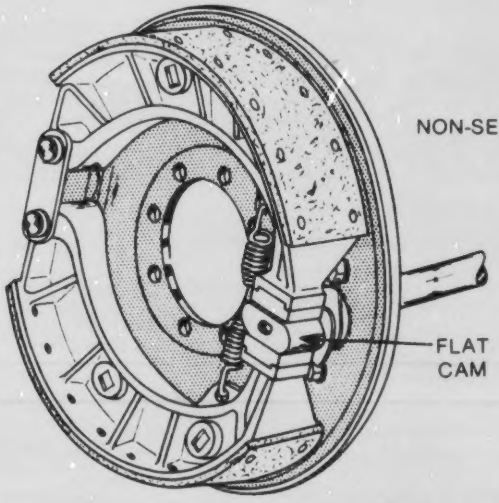
FORWARD BRAKING



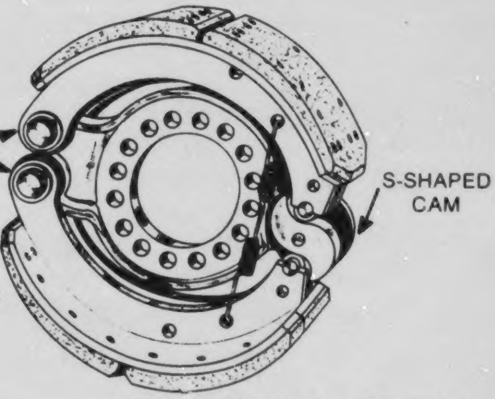
REVERSE BRAKING

(4-8) DUO-SERVO BRAKING ACTION

Courtesy of Bendix Corporation



Courtesy of Grey Rock, Division of Raybestos Manhattan Inc.



(4-9)
NON-SERVO BRAKES

Courtesy of Grey Rock, Division of Raybestos Manhattan, Inc.

NON-SERVO BRAKES

On Duo-Servo brakes the two brake shoes have an interrelating braking action (in effect one shoe serves the other). On Non-Servo brakes each shoe has a separate anchor and the shoes act independently against the drum. Non-Servo brakes are actuated by a hydraulic cylinder or a cam (s-shaped or flat). A retracting spring holds the shoes together against the activator (Figure 4-9).

The shoe which is first in direction of rotation on non-servo brakes is referred to as the primary shoe; the other is the secondary shoe. Often different types of lining material are used on the two shoes to improve the braking action.

Non-servo brakes actuated by hydraulic cylinders usually have separate adjusters for each shoe. Those having cam actuators are adjusted by a slack adjuster (discussed later).

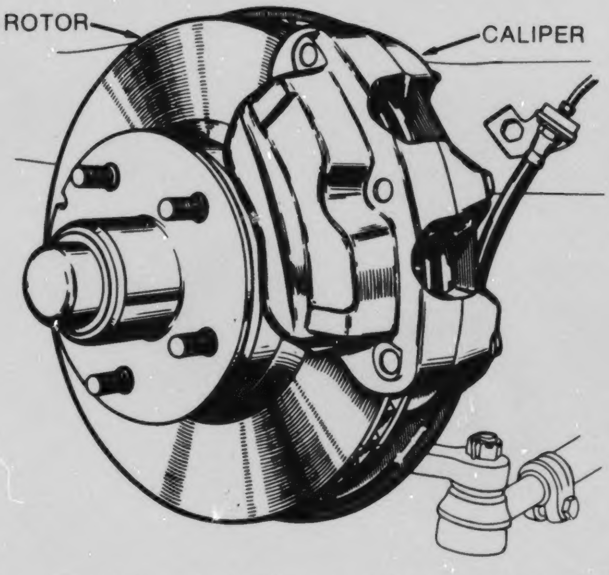
DISC BRAKES

Disc brakes are becoming more common on modern automobiles and trucks. There are two main types of disc brakes: caliper disc brakes and multi-disc brakes.

CALIPER DISC BRAKES

Caliper disc brakes (Figure 4-10) have:

- a disc or rotor that is secured to and rotates with the wheel hubs.
- a caliper assembly that squeezes the rotor on both sides to give the braking action. There are three designs of calipers: fixed, floating and sliding calipers.
- hydraulic wheel cylinder(s) or air to activate the caliper.



(4-10) TYPICAL FIXED CALIPER DISC BRAKE

Courtesy of Bendix Corporation

ADVANTAGES OF CALIPER DISC BRAKES

Disc brakes offer three major advantages over conventional drum brakes.

1. Resistance to Heat Fade. Disc brakes are generally more resistant to heat fade during high speed brake stops or repeated stops. The design of the disc brake rotor exposes more surface to the air and thus dissipates heat more efficiently.

2 Resistance to Water Fade. Disc brakes also are affected very little by water fade because the rotation of the rotor tends to throw off moisture.

3. More Straight-Line Stops. Due to their clamping action, disc brakes are less apt to pull and generally produce more uniform straight-line stops.

A number of truck manufacturers are using caliper disc brakes as original equipment and it's quite conceivable in the near future that most trucks will be using disc brakes.

MULTI-DISC BRAKES

Multi-disc brakes have been used for some time on heavy equipment such as wheel loaders, large haulage trucks and graders. Each brake has a number of smooth faced stationary discs splined to the wheel hub. The rotary discs fit between the stationary giving an alternating pack of rotating and stationary discs. Braking action occurs when the stationary discs are compressed against the rotating discs. Disc activation is by air or hydraulics. The discs are generally oil cooled to help prevent the brakes from fading.

POWER-ASSISTED HYDRAULIC BRAKES

There are three types of power-assisted brakes in common use today.

Vacuum
Air-over-oil
Oil-over-oil

Why are power-assisted brakes necessary?

1. Large vehicles require greater braking forces than manually operated brakes can supply.
2. Vehicles travelling at higher speeds require power brakes for a similar reason.
3. Power brakes are easier to operate requiring less effort from the driver.

All three types of power-assisted brakes operate according to a hydraulic principle similar to standard hydraulic brakes. The difference between the two is that power-assisted brakes have an additional mechanism that increases the braking force.

VACUUM-ASSISTED BRAKES

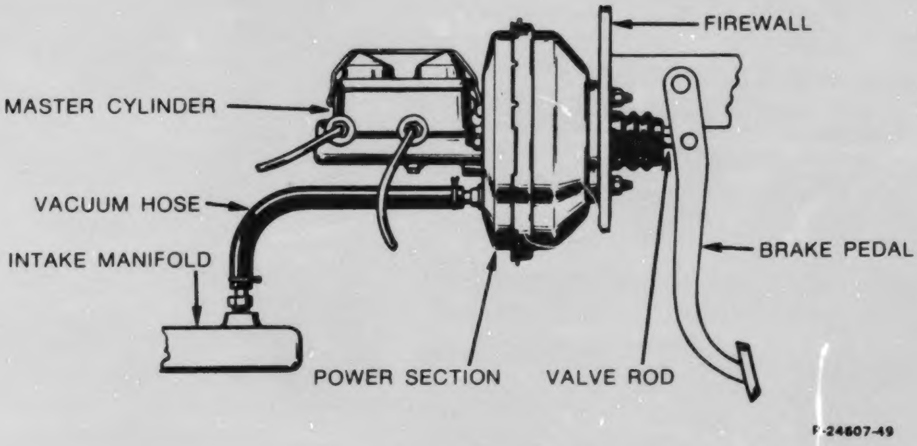
Vacuum-assisted brakes use a vacuum **brake booster** to increase the braking force of a conventional hydraulic brake system. Boosters are standard equipment on all large trucks with hydraulic brakes and on many light trucks and automobiles. Truck boosters are commonly referred to as **Multiplier boosters** (Hydrovacs), and automobile boosters as **Integral boosters.**

Integral and multiplier boosters operate similarily, but are mounted differently. The integral booster is firewall mounted directly to the master cylinder; its control valve is operated by the brake pedal. The multiplier booster is frame mounted away from the master cylinder; its control valve is operated by hydraulic pressure from the master cylinder.

POWER BOOSTER OPERATION

An integral booster consists of a power section, a master cylinder section, a vacuum line from the intake manifold and a brake pedal to operate it, as shown in Figure 4-11.

The power section is a vacuum chamber (the vacuum is created by the intake manifold) divided into two by a piston or a diaphragm. In the centre of the piston is a control valve. In released position the control valve is open and a vacuum exists on both sides of the piston. A slight movement of the brake pedal closes the control valve. Atmospheric pressure (air) is then fed into the rear of the piston. Since the pressure in air is greater than in a vacuum, the air will force the piston into the vacuum. Thus the piston is pushed by the atmospheric pressure trying to take up the vacuum. The piston in turn pushes on the master cylinder which activates the wheel cylinders. What has happened is that a slight force on the brake pedal has resulted in a strong force being applied to the brake master cylinder. The actual force on the master cylinder would be equal to the atmospheric pressure on the booster piston times the surface area of the rear of the piston (Force = Pressure × Area).

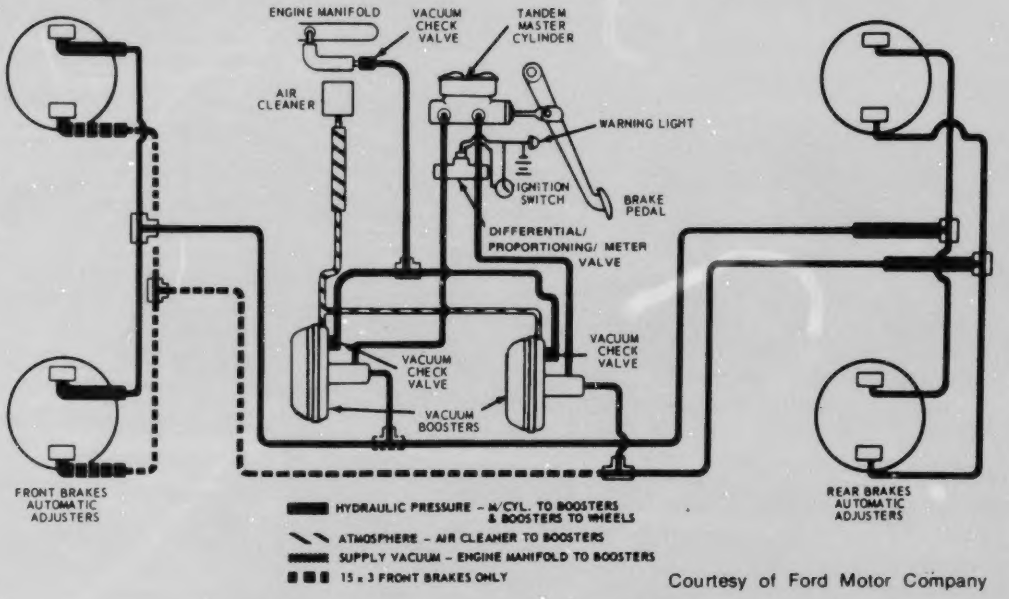


(4-11) FLUSH-MOUNTED MASTER-VAC

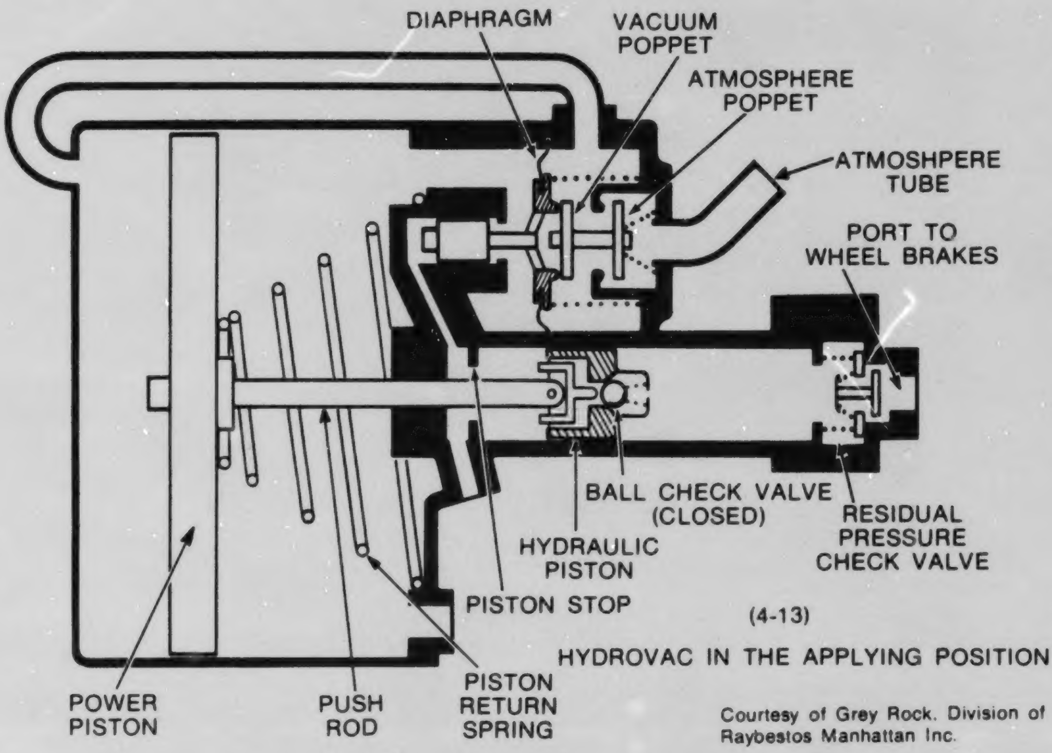
Courtesy of Bendix Corporation

The multiplier booster or hydrovac functions in a similar way except that its control valve(s) are operated by hydraulic pressure from the master cylinder. Figure 4-12 shows a split hydraulic brake system with dual hydrovac boosters. Figure 4-13 shows a hydrovac in detail.

(4-12)


ENGINE MANIFOLD
VACUUM CHECK VALVE
TANDEM MASTER CYLINDER
AIR CLEANER
WARNING LIGHT
IGNITION SWITCH
BRAKE PEDAL
DIFFERENTIAL/ PROPORTIONING/ METER VALVE
VACUUM CHECK VALVE
VACUUM CHECK VALVE
VACUUM BOOSTERS
FRONT BRAKES AUTOMATIC ADJUSTERS
REAR BRAKES AUTOMATIC ADJUSTERS
HYDRAULIC PRESSURE – M/CYL. TO BOOSTERS & BOOSTERS TO WHEELS
ATMOSPHERE – AIR CLEANER TO BOOSTERS
SUPPLY VACUUM – ENGINE MANIFOLD TO BOOSTERS
15 x 3 FRONT BRAKES ONLY

Courtesy of Ford Motor Company


DIAPHRAGM
VACUUM POPPET
ATMOSPHERE POPPET
ATMOSHPERE TUBE
PORT TO WHEEL BRAKES
BALL CHECK VALVE (CLOSED)
RESIDUAL PRESSURE CHECK VALVE
HYDRAULIC PISTON
PISTON STOP
POWER PISTON
PUSH ROD
PISTON RETURN SPRING

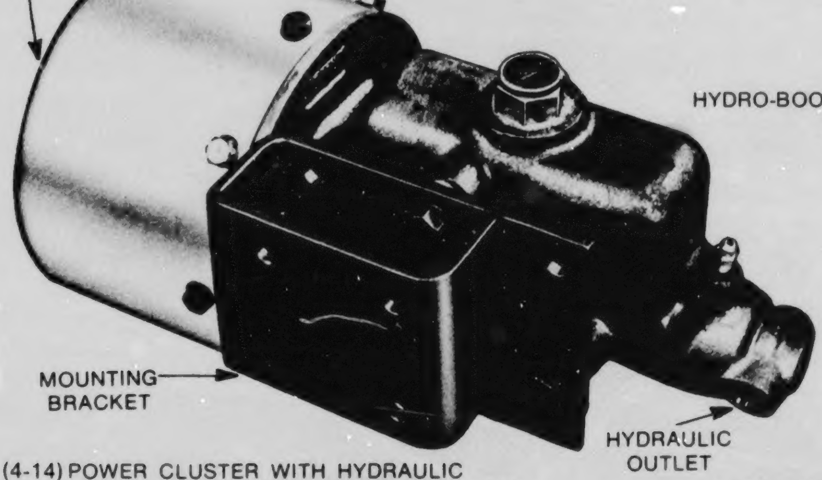
(4-13)

HYDROVAC IN THE APPLYING POSITION

Courtesy of Grey Rock, Division of Raybestos Manhattan Inc.

AIR-OVER-OIL BRAKES
(also called Air-Over-Hydraulic)

Air-over-hydraulic brakes are essentially conventional hydraulic brakes that are power-assisted. Power assist is gained through the power cluster (Figure 4-14). A power cluster is an air cylinder joined to a standard hydraulic master cylinder. Air pressure is applied in graduated amounts to the power cluster by a foot operated valve. The air pressure activates the air cylinder in the cluster which in turn applies force to the master cylinder. The master cylinder then sets the hydraulic system in motion to apply the brakes.



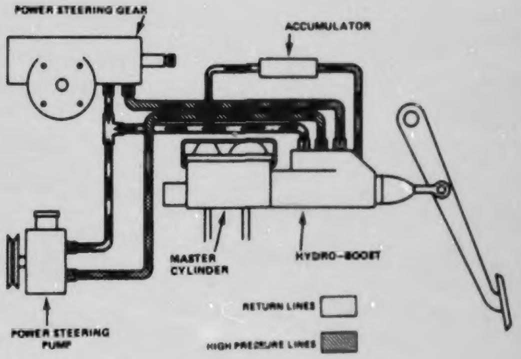
Courtesy of Wagner Electric.

(4-14) POWER CLUSTER WITH HYDRAULIC CYLINDER AND AIR CYLINDER POWER SECTION

Power clusters are capable of producing a pressure ratio increase of 15 : 1. For example, 100 P.S.I. air pressure applied to the air cylinder will create 1,500 P.S.I. master cylinder output.

Air-over-hydraulic systems differ in the number of power clusters and differ, as do most hydraulic systems, in the number of wheel cylinders, size of lining and diameter of brake drums.

Air-over-hydraulic brakes are often preferred to air brakes on larger off-highway vehicles such as trucks and loaders because the air-over-oil brakes are less vulnerable to rough terrain. Air brakes have a number of relatively large exposed parts that would be subject to damage by the uneven, rocky ground that off-highway vehicles work in. Air over hydraulic brakes, on the other hand, are more compact; they have only a small line leading to each wheel assembly; and are therefore less likely to be damaged.



(4-15)
HYDRO-BOOST HYDRAULIC SCHEMATIC
Courtesy of Bendix Corporation

OIL-OVER-OIL BRAKES

With the help of a booster assembly equipped with an accumulator, oil-over-oil brakes combine hydraulic pressure from a power steering system with a conventional hydraulic brake system. The accumulator is a safety system that supplies enough fluid to stop the vehicle when the engine stalls. Figure 4-15 shows an oil-over-oil brake system.

Pushing the brake pedal, opens a control valve in the power booster and pressurized oil from the steering system enters the booster. This oil pushes the piston in the booster which in turn applies force to the master cylinder. The master cylinder then sets the hydraulic system in motion to apply the brake shoes. Note that there is no mixing of steering fluid and brake fluids. The oil from the steering system stops at the power booster; it does not mix with the brake fluid from the hydraulic brake system.

Power boosters in oil-over-oil brakes, like power clusters in air-over-hydraulic brakes, are capable of producing a high increase in force with a minimum effort from the operator.

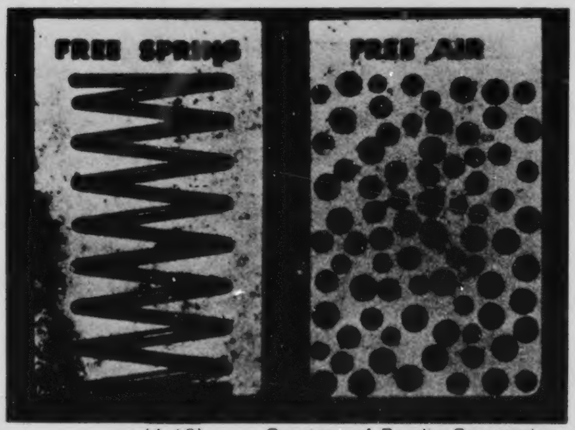
Oil-over-oil brakes should not be confused with straight hydraulic brakes such as those found on a cat loader. These brakes may appear to be power-assisted but they are not; they use pressure from the machine's hydraulic system in graduated amounts to apply the brakes.

The common name for oil-over-oil brakes is **hydro-boost brakes.** Hydro-boost brakes are used by General Motors on some of their light to mid-weight trucks. Larger trucks that use oil-over-oil brakes have an emergency system other than an accumulator in case the truck engine stalls. An electric motor will cut in and run a hydraulic pump, allowing the vehicle to be safely braked.

AIR BRAKES

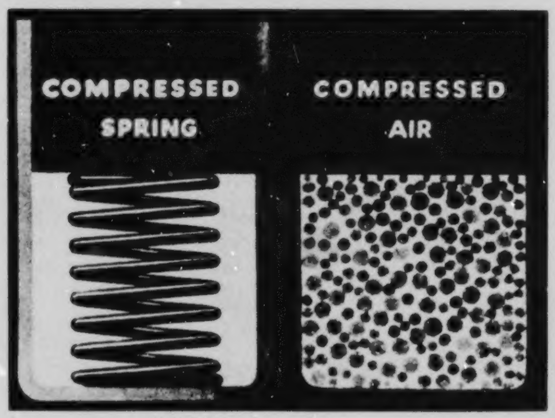
Air brakes are the most common brakes used on both on-highway and off-highway trucks and trailers. Many types of construction equipment too numerous to mention also use air brakes. Air brakes transmit force and motion through compressed air. Compressed air is defined as air that is forced to occupy a space less than it normally would in the atmosphere. Atmospheric air pressure at sea level is 14.7 P.S.I. Compressed air is measured in P.S.I. above atmospheric pressure. For example, a compressed air measurement of 50 P.S.I. means 50 P.S.I. above standard atmospheric pressure of 14.7.

The energy of compressed air can be compared to the energy of a coil spring. A coil spring in its free state and a container full of air at atmospheric pressure have no potential energy (Figure 4-16).



(4-16) Courtesy of Bendix Corporation

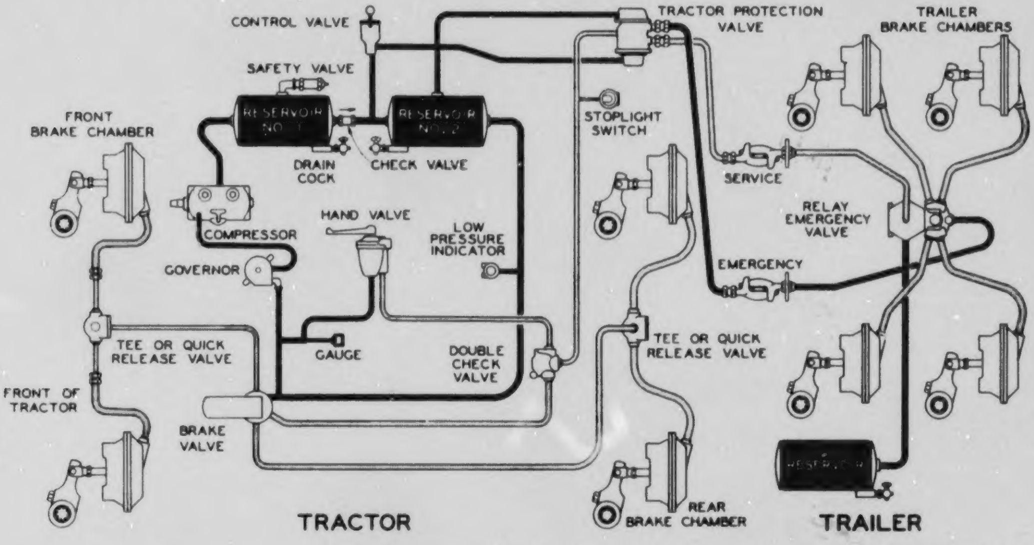
If the spring is compressed, it then has potential energy which can be put to work. Compressed air has a similar work potential (Figure 4-17).



(4-17) Courtesy of Bendix Corporation

A standard air brake system (Figure 4-18), is made up of the following components.

1. **Compressor** — pumps air under pressure into the reservoir. It is driven, cooled and lubed by the main engine.
2. **Reservoirs** — receive and store the compressed air.
3. **Governor** — controls the air in the reservoirs.
4. **Valves** — control the application and release of the brakes.
5. **Safety Valves** — protect the tractor and trailer air supply in case of an emergency.
6. **Brake Chambers** — receive the graduated amounts of compressed air and convert it into the mechanical force and movement needed to apply the brakes.
7. **Slack Adjuster** — part of the mechanism that applies the force from the brake chamber to the brake shoes. Slack adjusters also provide the means to adjust air brakes to compensate for normal running wear.
8. **Foundation Brake Assemblies** — supply the braking action.

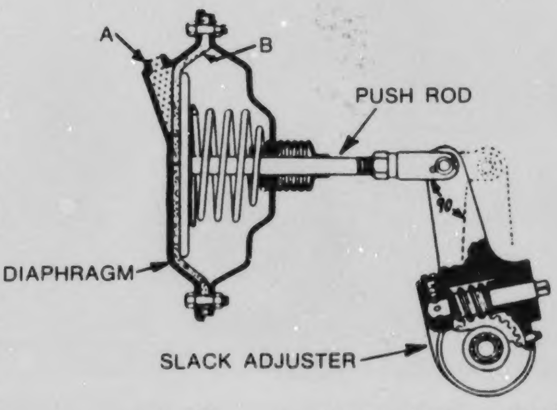

CONTROL VALVE
SAFETY VALVE
RESERVOIR NO. 1
RESERVOIR NO. 2
DRAIN COCK
CHECK VALVE
FRONT BRAKE CHAMBER
COMPRESSOR
HAND VALVE
LOW PRESSURE INDICATOR
GOVERNOR
TEE OR QUICK RELEASE VALVE
GAUGE
DOUBLE CHECK VALVE
FRONT OF TRACTOR
BRAKE VALVE
TRACTOR
TRACTOR PROTECTION VALVE
STOPLIGHT SWITCH
TRAILER BRAKE CHAMBERS
SERVICE
RELAY EMERGENCY VALVE
EMERGENCY
TEE OR QUICK RELEASE VALVE
RESERVOIR
REAR BRAKE CHAMBER
TRAILER

(4-18) Courtesy of Grey Rock, Division of Raybestos Manhattan Inc.

Many improvements have been made on this basic air brake design. For example changes in piping (referred to as schedules) have made a faster acting brake that has a greater degree of safety. Such improvements to the basic design will be dealt with in later courses. The present material is only concerned with a standard air brake system.

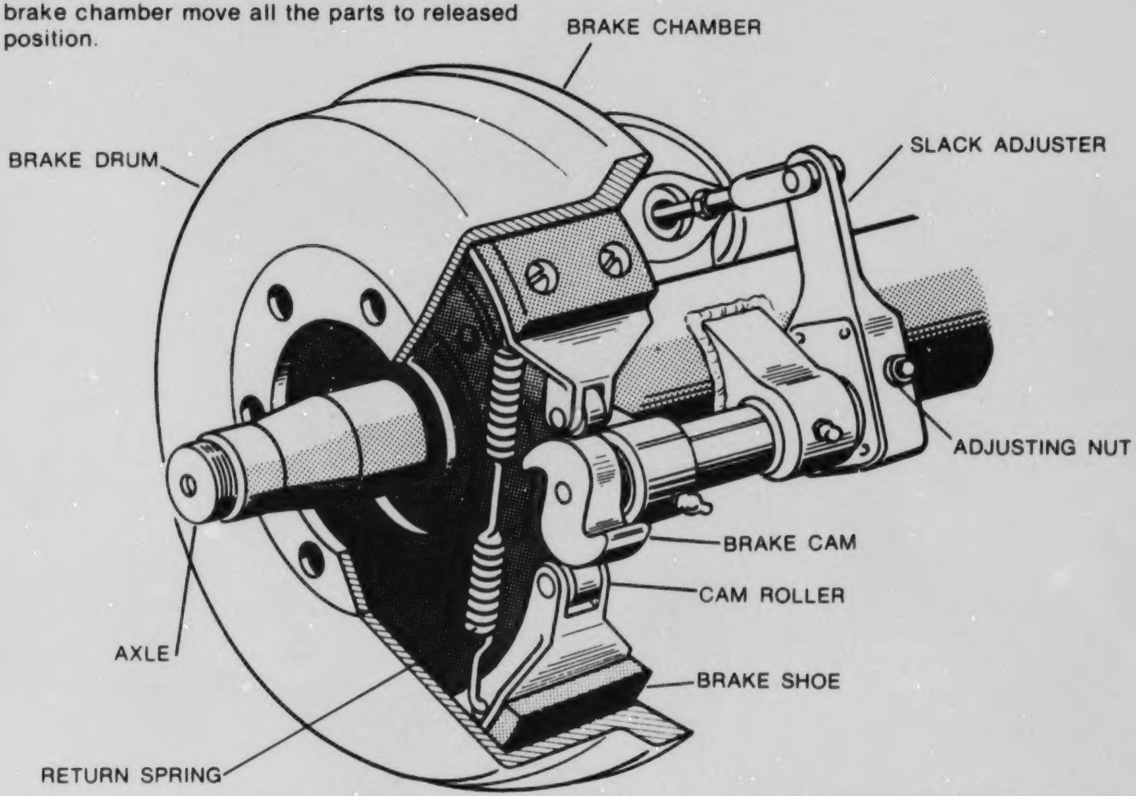
The wheel assembly is the most likely area of the air system you will be involved with at this level of training.

The brake chamber shown in Figure 4-19 illustrates the action that takes place at the wheel assembly. Air enters the chamber at point (A) and acts against the diaphragm to move the push rod against the slack adjuster.


A
B
PUSH ROD
90°
DIAPHRAGM
SLACK ADJUSTER

(4-19) Courtesy of Grey Rock, Division of Raybestos Manhattan Inc.

Turning to Figure 4-20, the slack adjuster rotates the cam shaft which forces the shoes out against the brake drum. When air is released from the brake chamber, return springs in the brake assembly and in the brake chamber move all the parts to released position.


BRAKE CHAMBER
BRAKE DRUM
SLACK ADJUSTER
ADJUSTING NUT
BRAKE CAM
CAM ROLLER
AXLE
BRAKE SHOE
RETURN SPRING

(4-20)

Courtesy of Grey Rock, Division of Raybestos Manhattan Inc.

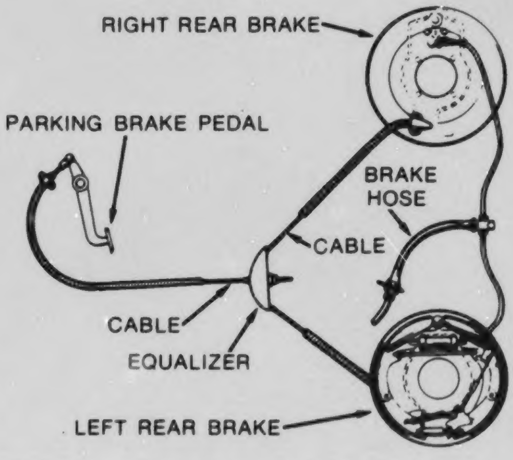
EMERGENCY OR PARKING BRAKES

An emergency or parking brake is standard equipment on all vehicles. It may be a separate brake on its own, i.e., a drive shaft parking brake, or may be an integral part of the service brakes.

INTEGRAL PARKING BRAKE

Integral parking brakes (Figure 4-21) are controlled by a brake pedal or hand lever and cables. The cables operate mechanical levers which force the service brake shoes against the drum.

Since integral parking brakes are primarily used on automobiles and light trucks, they won't be dealt with any further here.


RIGHT REAR BRAKE
PARKING BRAKE PEDAL
BRAKE HOSE
CABLE
CABLE
EQUALIZER
LEFT REAR BRAKE

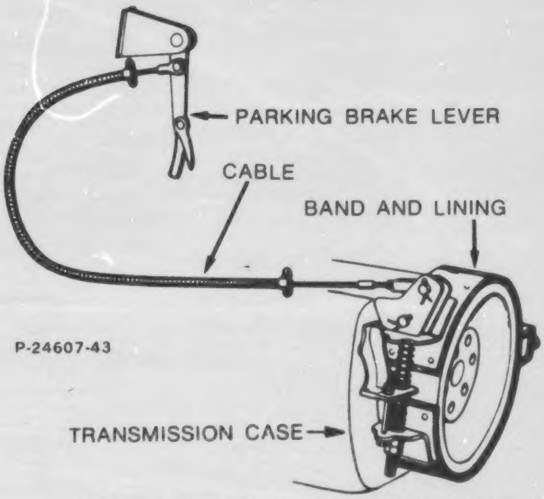
(4-21) TYPICAL INTEGRAL PARKING BRAKE

P-24607-44

Courtesy of Bendix Corporation

DRIVE SHAFT PARKING BRAKES

Drive shaft parking brakes are mounted at the rear of the transmission where the drive shaft is connected to the output shaft. These parking brakes are mechanically applied by a hand lever connected to cables or rods. Figure 4-22 shows an external band drive shaft parking brake.

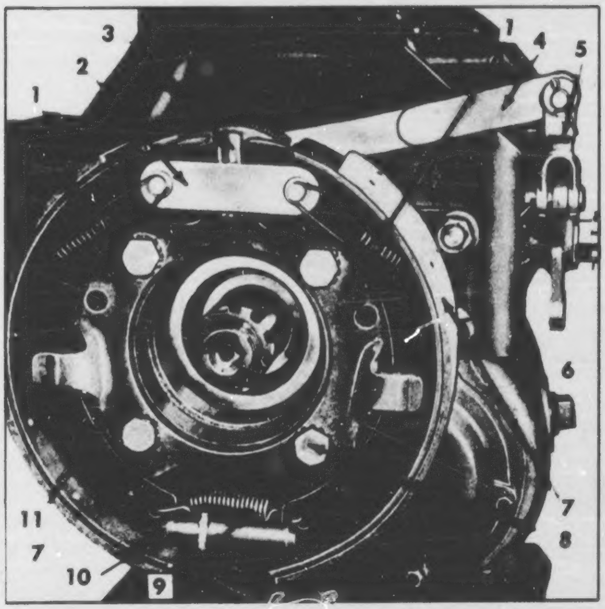


(4-22) EXTERNAL BAND PARKING BRAKE

Courtesy of Bendix Corporation

Three common types of drive shaft parking brakes are:

1. Internal expanding shoe parking brake (Figure 4-23). Note the control lever (4) that applies the brake and also note the adjusting screw (10).

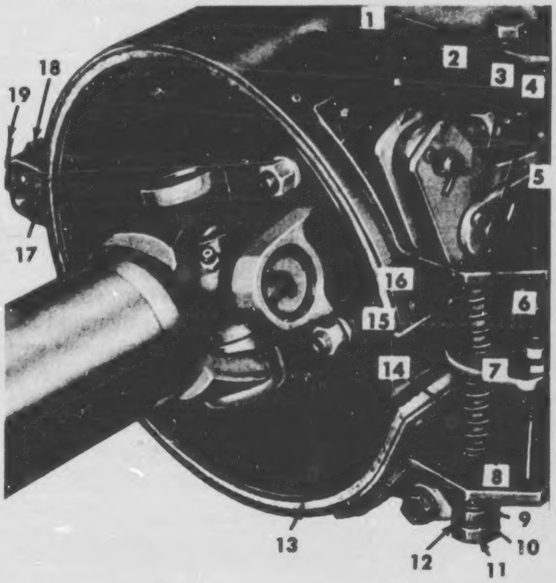


1	Return Springs	7	Brake Shoe
2	Anchor Pin Link	8	Plate Bolt
3	Camshaft	9	Adjusting Screw Spring
4	Control Lever	10	Adjusting Screw
5	Link	11	Support Plate
6	Relay Lever		

(4-23) INTERNAL EXPANDING BAND PARKING BRAKE

Courtesy of General Mortors Corporation

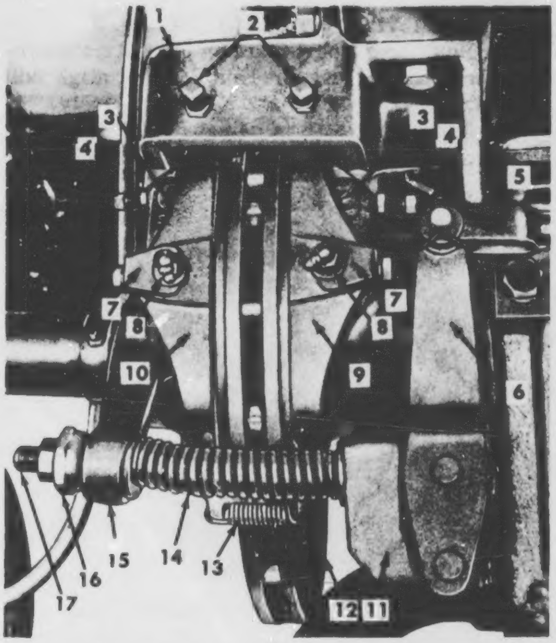
2. External contracting band parking brake (Figure 4-24). Note that the brake band is outside of the drum.



1	Brake Band	11	Lock Nut
2	Cams	12	Lock Washer
3	Links	13	Brake Linings
4	Clevis Pins	14	Release Springs
5	Cam Shoe	15	Brake Drum
6	Lock Nut	16	Adjusting Bolt
7	Adjusting Nut	17	Anchor Bar
8	Locating Bolt	18	Anchor Screw
9	Washer	19	Lock Wire
10	Adjusting Nut		

(4-24) EXTERNAL CONTRACTING BAND PARKING BRAKE

3. Disc and pads (Tru Stop) (Figure 4-25). Note the disc 12 between the two brake shoe friction pads (9) and (10). This disc and pad construction is a very effective parking brake and is used on many vehicles.



1 Brake Support Bracket
2 Parallel Adjusting Screws
3 Front Lever Arm Pin
4 Pin Retaining Screw
5 Brake Cable Clevis
6 Brake Lever
7 Brake Shoe Pin Retainer
8 Brake Shoe Pin
9 Front Brake Shoe
10 Rear Brake Shoe
11 Front Lever Arm
12 Brake Disc
13 Tension Spring
14 Spring
15 Rear Lever Arm
16 Adjusting Nut
17 Tie Rod

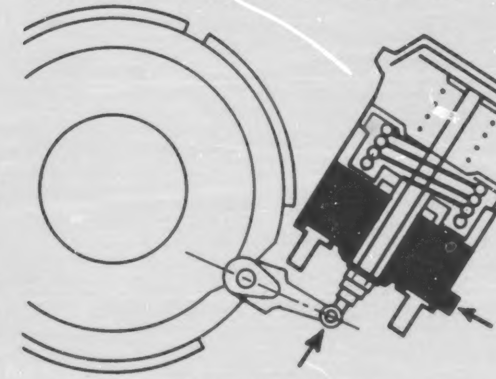
(4-25) TRU-STOP TYPE PARKING BRAKE

Courtesy of General Motors Corporation

SPRING BRAKES

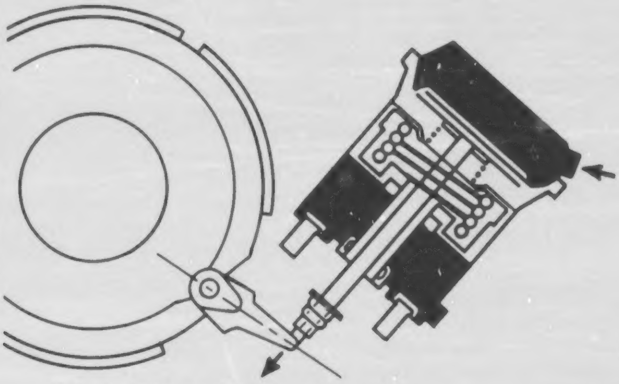
Vehicles with air brakes may have a drive shaft parking brake, but they are more likely to have spring brakes. Spring brakes could be referred to as integral parking brakes because they work on the service brake shoes. There are a number of types of spring brakes but they all operate on the basic principle of spring applied and air released. Once applied, the brakes cannot be released until sufficient air pressure is fed into the chamber to retract the spring. Spring brakes are very positive and very safe. Operation of a typical spring brake is illustrated in Figure 4-26.

(4-26) HOW THE SPRING BRAKE WORKS



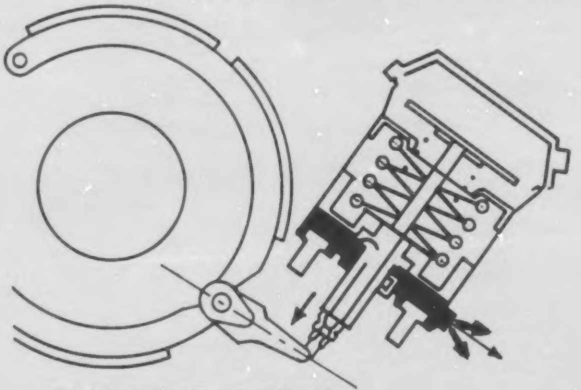
Normal — Brakes Released

Air pressure from service system acting on the piston compresses the spring, releasing the brakes.



Service Brake Application

Air pressure from the service brake system acts on the diaphragm applying the brakes.



Parking Brake Application

Exhausting the air from the chamber releases the piston, allowing the spring to force it and the push rod forward, applying the brakes.

Courtesy of the Government of British Columbia Airbrake Manual

BRAKE FLUID

Brake fluid is one of the more important components of the hydraulic brake system because it ties all the other components of the system together into an operating unit. Hydraulic brake fluid is a specially blended liquid that provides a means of transmitting hydraulic pressure from the master cylinder to the wheel cylinder. The fluid is a composite of glycerine alcohol and performance additives. It is important to note that brake fluid is not a petroleum product and should never be mixed with oil. Brake fluid and oil are incompatible. Any oil added to brake fluid in a hydraulic brake system would quickly destroy the system's rubber parts. For this reason it is a good habit to refer to the fluid in a brake system as brake fluid and not brake oil.

Having cautioned against the use of the term brake oil, an exception must be mentioned. By far the majority of hydraulic brake systems use brake fluid, but there are a few that use oil. For example, large mine haulage trucks use a petroleum based oil in their hydraulic brake systems.

Federal laws require that brake fluid must meet SAE (Society of Automotive Engineers) specifications. The current SAE specification for Brake Fluid is J1703. Fluids used should meet or exceed this standard.

Brake fluid must possess the following characteristics:

1. Viscosity (free flowing at all temperatures).
2. High boiling point (remain liquid at highest operating temperature).
3. Non-corrosive (must not attack metal or rubber parts).
4. Water tolerance (must be able to absorb and retain up to 2% moisture that collects in the system).
5. Lubricating ability (must lubricate piston and cups to reduce wear and internal friction).
6. Low freezing point (must not freeze even at lowest operating temperatures).

CHANGING BRAKE FLUID

Due to Usage

Through use, brake fluid loses some of its original qualities and may become contaminated. When performing major brake work, it is good practice to flush the hydraulic system to remove old fluid and replace it with clean brake fluid. Also, if any of the hydraulic system parts are corroded or the fluid is discolored, the hydraulic system should be flushed and filled with clean brake fluid.

Due to Contamination

Soft or swollen rubber parts in the hydraulic system are an indication that the brake fluid is contaminated. If this happens:

- — the old fluid should be drained from the system.
- — all cups and seals should be replaced.
- — the hydraulic system should be flushed with clean brake fluid or alcohol.
- — the system should be refilled with clean brake fluid.

HANDLING AND STORING BRAKE FLUID

The following basic rules should be followed when handling and storing brake fluid.

1. Keep the brake fluid clean. Do not get any foreign material in the fluid.
2. Be very careful to keep any petroleum product (gasoline, kerosene, oil, grease, etc.,) from getting into the brake fluid.
3. Use only clean containers for dispensing brake fluid. Do not use containers contaminated with dirt, oil, grease, rust, etc.
4. Always cover or cap brake fluid containers when not actually dispensing the fluid. If containers are left open or uncovered, the fluid tends to absorb moisture from the air.
5. Discard old brake fluid drained from the hydraulic system. Used brake fluid is contaminated to some degree.
6. Store brake fluid containers in a clean, dry place.

QUESTIONS — BRAKES

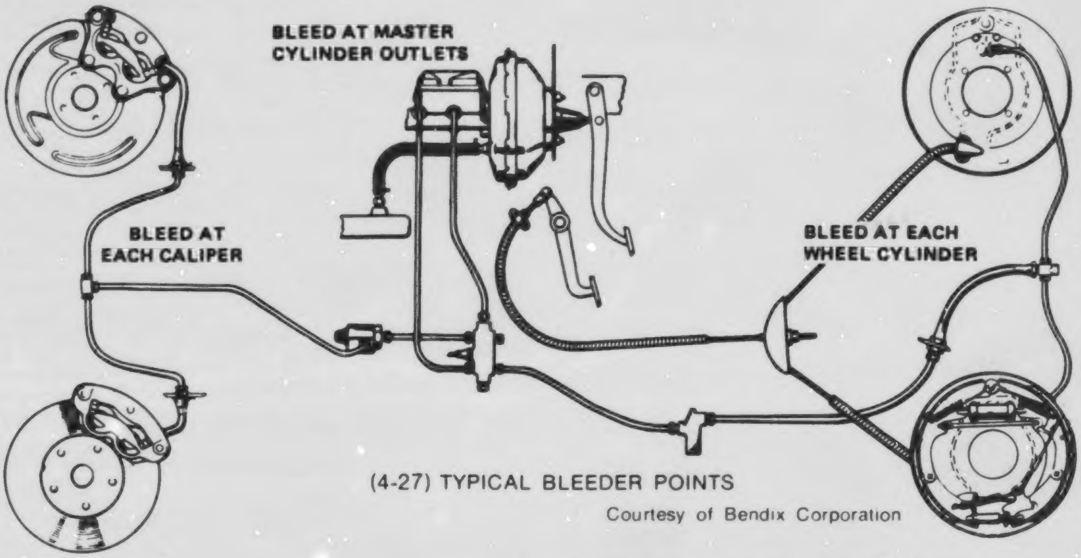
1. Brakes convert a vehicle's motion energy into:
   - (a) drag energy
   - (b) friction energy
   - (c) heat energy
   - (d) all of the above
2. The strength of frictional force between two surfaces is called their ____________________ .
3. What are two vehicle operating practices that can be very hard on brakes?
4. What are the three types of brake systems used on heavy duty vehicles?
5. Hydraulic brakes work on the basic principle of transmitting force and motion through the medium of:
   - (a) trapped air
   - (b) hydraulic lines
   - (c) a confined fluid
   - (d) all of the above
6. In a hydraulic brake system what happens to the flow of pressurized fluid that the master cylinder sends out to the wheel cylinder to apply the brakes.
7. List the three common types of power-assisted hydraulic brakes.
8. Briefly explain the differences between an Integral and a Multiplier vacuum assist brake system. Give an example where each is used.
9. Briefly explain the difference between a duo-servo and a non-servo foundation brake.
10. In an air-over-oil hydraulic brake system, what applies force to the master cylinder setting the hydraulic system in motion to apply the brakes:
    - (a) air reservoir
    - (b) air compressor
    - (c) air cylinder or power cluster
    - (d) none of the above
11. An advantage of multi-disc brakes is that the disc can be ____________ in oil.
12. What are the three main parts of a caliper disc brake?
13. What does the oil-over-oil Hydro-Boost power brake system use as a source of assist?
14. Air brakes work on the principle of transmitting force and motion through the medium of:
    - (a) compressed fluid
    - (b) compressed air
    - (c) compressed fluid and air
    - (d) none of the above
15. Spring brakes operate on the principle of:
    - (a) air applied and spring released
    - (b) spring applied and air released
    - (c) spring applied and hydraulic released
    - (d) spring applied and spring released
16. Is the fluid used in the majority of hydraulic brakes a petroleum product? Briefly describe the composition of brake fluid.
17. What does the phrase bleeding the brakes refer to?

PREVENTIVE MAINTENANCE AND ADJUSTMENTS ON BRAKES

Good preventive maintenance practices on brakes is essential since brakes are so important to the safe operation of a vehicle. As a first year apprentice you will likely do brake checks and adjustments, and make minor brake repairs. Until familiar with the location and number of adjusters and adjusting procedures, read the service manual before attempting to make any brake adjustments.

BLEEDING HYDRAULIC BRAKES

Hydraulic braking systems will only work if they are free of air. Whenever work is done on the wheel or master cylinders, air gets into the system and has to be released. Each wheel cylinder has a bleed valve and some master cylinders also have one. Figure 4-27 shows typical bleeding points.


BLEED AT MASTER CYLINDER OUTLETS
BLEED AT EACH CALIPER
BLEED AT EACH WHEEL CYLINDER

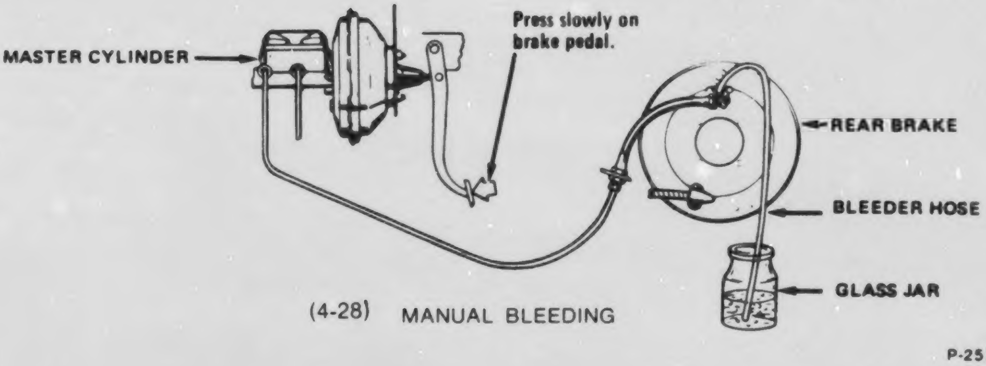
(4-27) TYPICAL BLEEDER POINTS

Courtesy of Bendix Corporation

There are two methods of bleeding:

1. Manual bleeding
2. Pressure bleeding

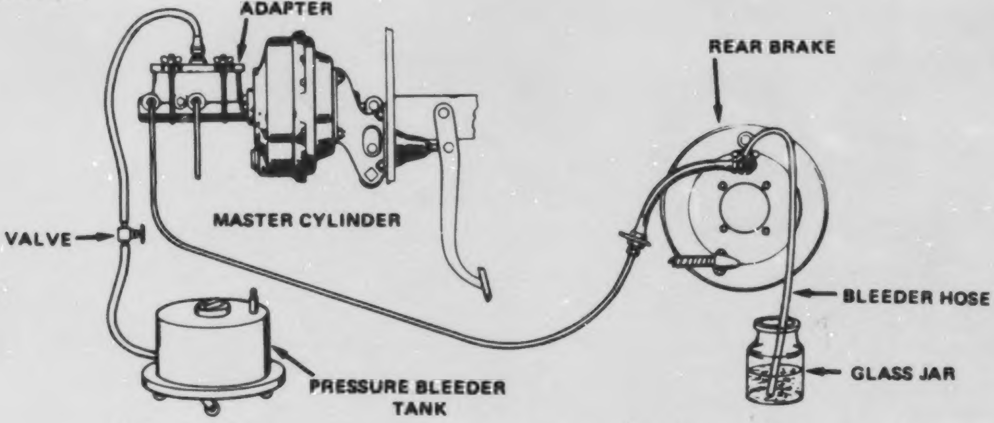
To manually bleed a hydraulic system first fill the reservoir. Then while one person slowly pumps the brake pedal, another person opens each bleeder, one at a time, to free the air. Use a bleeder hose and a glass jar to collect the fluid, as shown in Figure 4-28.


MASTER CYLINDER
Press slowly on brake pedal.
REAR BRAKE
BLEEDER HOSE
GLASS JAR
P-25162D

(4-28) MANUAL BLEEDING

Courtesy of Bendix Corporation

To pressure bleed a hydraulic system connect a pressure bleeder tank to the master cylinder (Figure 4-29) and then open one bleeder at a time to free the air. Again, collect the fluid in a glass jar.



(4-29) PRESSURE BLEEDING

Courtesy of Bendix Corporation

If at any time a brake line has to be disconnected, be sure to clean the area around the fittings before disconnecting it. Cap the line once it is unfastened. As a rule the system will require a slight bleeding when the line is reconnected. To complete the job of bleeding the brakes, one person should pump the brakes while another person checks for leaks.

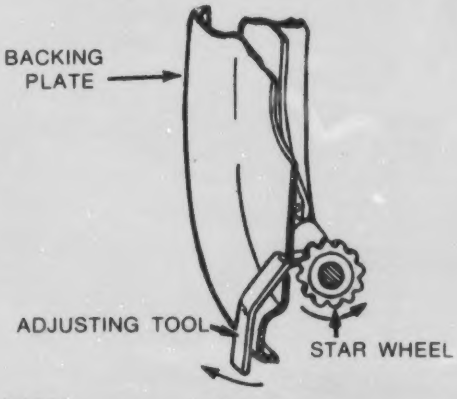
ADJUSTING HYDRAULIC BRAKES

Not all brakes require adjusting; some are self adjusting and some require no adjustment. Brakes that do require adjustment need to have the wear on the brake linings compensated for. The frequency of adjustment depends on the condition and type of brakes, the type of work the vehicle is doing, and the operator (some operators are harder on brakes than others).

GENERAL POINTS ON BRAKE ADJUSTMENT

1. Determine the need for adjustment by checking the amount of pedal travel. If the pedal travels more than half way to the floor, adjustment is usually indicated.
2. Park the vehicle on a level area.
3. Block one front wheel and one back wheel for safety.
4. Jack up one wheel at a time so each wheel can be rotated while it is being adjusted.
5. Tighten the adjustment until the wheel will not rotate, and then back it off until the wheel is free and a **very** slight drag is felt. Be sure you know how many adjusters are used on each wheel. Some wheels have two adjusters, one for each shoe. Also watch for adjustable anchors (a threaded bolt with a lock nut projecting from the backing plate) on some brake systems. **Do not** adjust these anchors; they are adjusted only after a major brake overhaul.

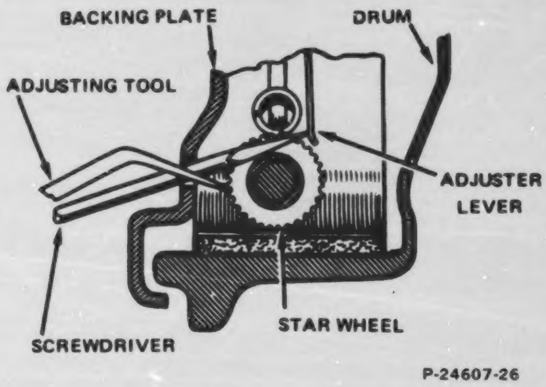
The following figures show some of the methods used to adjust hydraulic brakes. A manual adjuster, as shown in Figure 4-30, usually has an access hole in the backing plate. A hook shaped tool fits through the hole and turns the adjuster wheel.



(4-30)

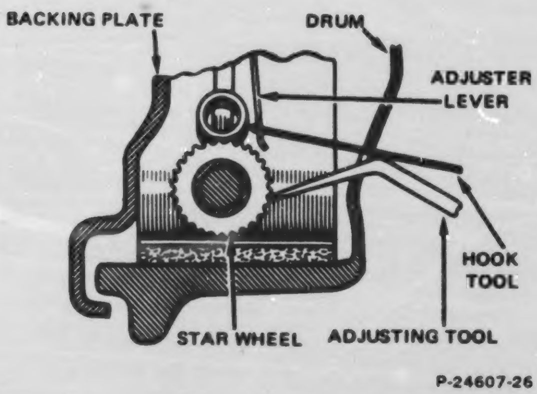
Courtesy of Bendix Corporation

Some self adjusters may require an initial adjustment, or may have to be adjusted manually if they are not self adjusting properly. They can be adjusted by holding the internal adjusting lever away from the star wheel, and then turning the wheel with a hook shaped tool. The method of holding the adjusting lever away from the wheel will depend on where the access hold or adjusting slot is located (Figure 4-31).


BACKING PLATE
DRUM
ADJUSTING TOOL
ADJUSTER LEVER
STAR WHEEL
SCREWDRIVER
P-24607-26

(4-31) WITH ADJUSTING SLOT IN BACKING PLATE

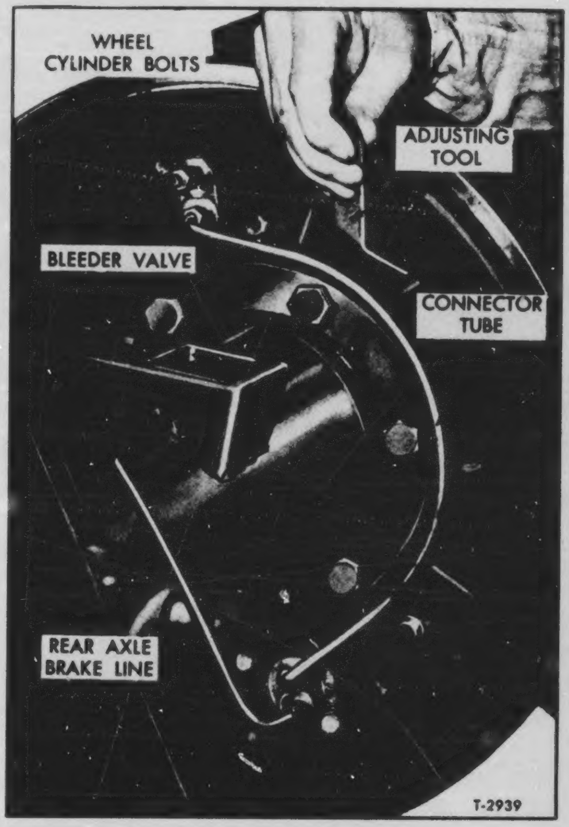
Courtesy of Bendix Corporation


BACKING PLATE
DRUM
ADJUSTER LEVER
HOOK TOOL
STAR WHEEL
ADJUSTING TOOL
P-24607-26

(4-31) WITH ADJUSTING SLOT IN BRAKE DRUM

Courtesy of Bendix Corporation

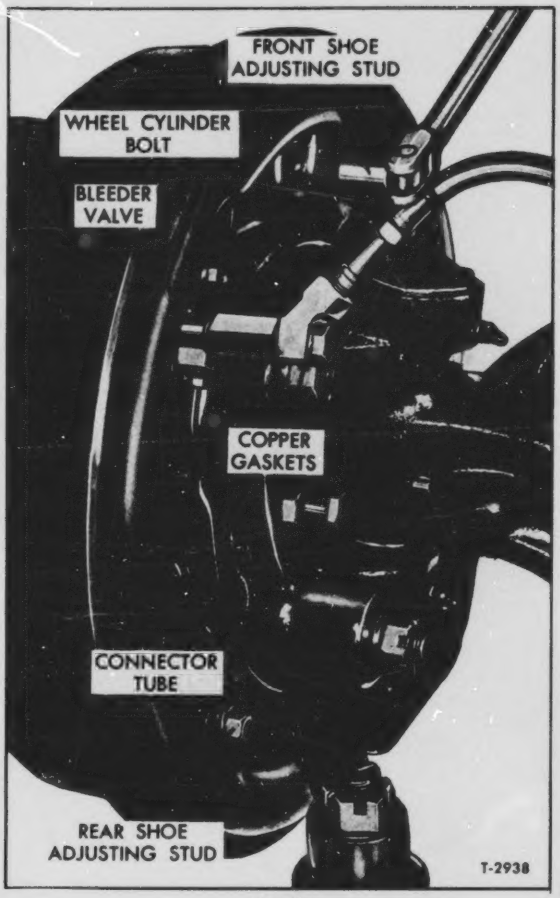
Figure 4-32 shows a large wheel assembly that has a star wheel brake adjuster. Probably there is another adjuster located 180° from this one.


WHEEL CYLINDER BOLTS
ADJUSTING TOOL
BLEEDER VALVE
CONNECTOR TUBE
REAR AXLE BRAKE LINE
T-2939

(4-32)

Courtesy of General Motors Corporation

The wheel assembly in Figure 4-33 uses a stud adjuster. The direction that the stud is turned to adjust the shoes will vary (see service manual). Note there are two studs, one for each shoe.

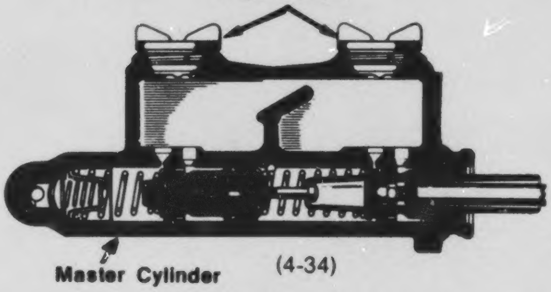

FRONT SHOE ADJUSTING STUD
WHEEL CYLINDER BOLT
BLEEDER VALVE
COPPER GASKETS
CONNECTOR TUBE
REAR SHOE ADJUSTING STUD
T-2938

(4-33)

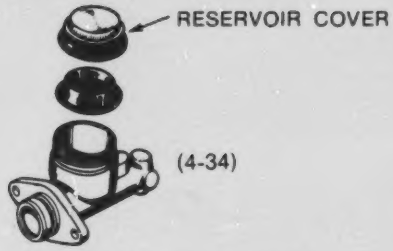
Courtesy of General Motors Corporation

6. While making brake adjustments, be observant for damaged lines, leaks, etc. If a brake line has to be disconnected on a machine such as a wheel loader which has full hydraulic brakes and an accumulator, be sure to shut the engine down and apply the brakes several times to bleed the accumulator. This practice is to prevent you from being showered with oil. Similarly bleed down the accumulator on an oil-over-oil system and the air from an air-over-oil system.

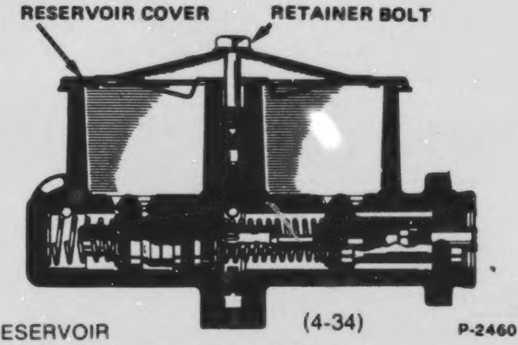
7. After the brake adjustment is completed, always check the fluid level. If the level is down, clean the area around the top of the reservoir before removing the filler plug or lid. This practice will prevent dirt from getting into the fluid. Figure 4-34 shows various types of reservoir filler caps and lids.


FILLER CAPS
Master Cylinder

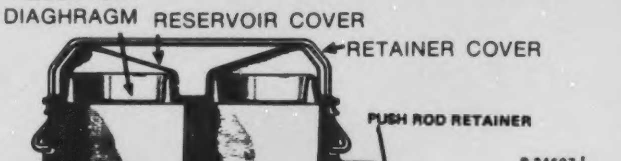
(4-34)


RESERVOIR COVER

(4-34)


RESERVOIR COVER
RETAINER BOLT

(4-34) P-24607-G


RESERVOIR DIAGHRAGM
RESERVOIR COVER
RETAINER COVER
PUSH ROD RETAINER
P-24607-I
DUST BOOT
PUSH ROD

(4-34) Courtesy of Bendix Corporation

Note that all current master cylinder reservoirs have a diaphragm across the top of the fluid to prevent air from getting at the fluid. The diaphragm is necessary because brake fluid has an affinity for taking moisture from the air. The diaphragm is a soft flexible membrane which follows the fluid level as it goes down in the reservoir. The membrane keeps air away from the fluid, but still allows a normal atmosphere pressure above the fluid.

Brake fluid can be topped up, if low with the approved brake fluid. However, if very much fluid is needed, it's quite possible there is a leak. Normally, little brake fluid has to be added and it shouldn't have to be added very often.

If the vehicle is equipped with vacuum-assist power brakes, a quick method to check booster operation is as follows:

(a) Before starting the engine, pump the brake pedal several times to exhaust all the vacuum.

(b) Hold your foot firmly on the brake pedal.

(c) Start the engine. If the booster is functioning the pedal will drop slightly as the engine starts.

Obviously, the brakes can also be checked by moving the vehicle and applying the brakes.

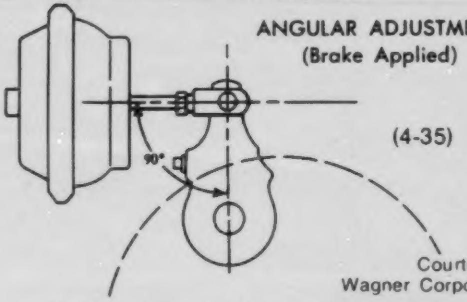
ADJUSTING AIR BRAKES

Air brakes, like hydraulic brakes, need to be adjusted to compensate for running wear. Although adjustment is important on both types of brakes, adjustment is probably more critical on air brakes. A driver has a chance to counter-act faultily adjusted hydraulic brakes, but he doesn't have the same chance on air brakes. If the pedal is low on first application of a hydraulic brake, pumping the pedal will displace more fluid which will further expand the wheel cylinders and apply the brakes. The brake chamber on air brakes, on the other hand, has a specific volume and stroke and once the maximum stroke is reached, the brakes cannot be pumped up. For this reason it is most important that air brakes be kept properly adjusted. It's worth noting that very few air brakes have failed from loss of air; the most likely cause is that the brakes were badly out of adjustment.

Air brake adjustment for an S-cam brake should be done as follows:

Two persons are needed, one person should apply the brakes while the other checks, at each wheel, the angle between the slack adjuster and the push rod of the brake chamber. The angle should be 90° or slightly greater, as shown in Figure 4-35. When the angle is less than 90° there is too much push rod travel and the slack adjuster should be adjusted.

ANGULAR ADJUSTMENT
(Brake Applied)



(4-35)

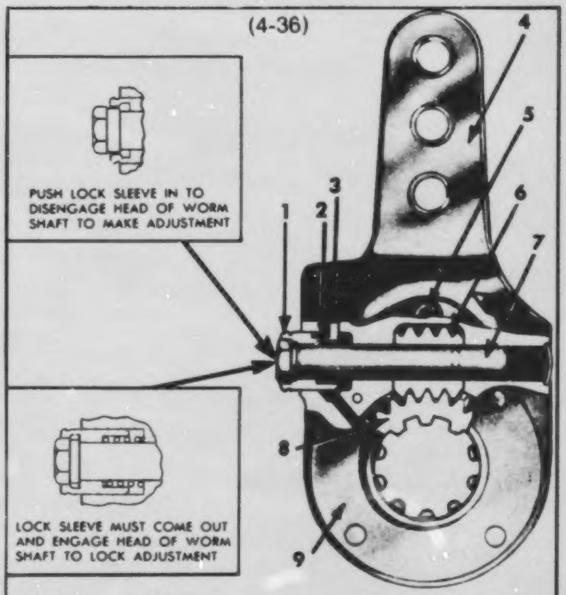
Courtesy of
Wagner Corporation

Having found the applied push rod and slack adjuster angle is less than 90°, the most accurate method of correcting them is to:

(a) Jack up the wheel, as was done with hydraulic brakes.

(b) Turn the adjusting nut on the slack adjuster to rotate the cam and bring the shoes in contact with the drum. Figure 4-36 shows a typical slack adjuster. Note how the worm shaft adjuster bolt (7) turns the worm (6) which in turn rotates the gear (8). The gear then rotates the shaft of the cam which is splined to it.

(4-36)

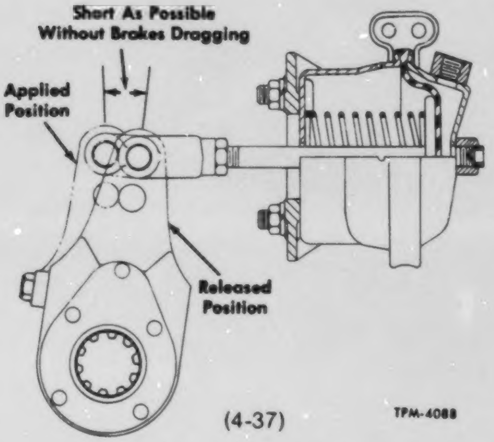

PUSH LOCK SLEEVE IN TO DISENGAGE HEAD OF WORM SHAFT TO MAKE ADJUSTMENT
LOCK SLEEVE MUST COME OUT AND ENGAGE HEAD OF WORM SHAFT TO LOCK ADJUSTMENT
1
2
3
4
5
6
7
8
9

1 Lock Sleeve
2 Spring
3 Dowel
4 Lever
5 Rubber Plug
6 Worm
7 Worm Shaft
8 Gear
9 Cover Plate

T-2325

Courtesy of General Motors Corporation

(c) Adjust the brake until the wheel is tight and then back it off enough to get the shortest possible push rod stroke without the brakes dragging, as illustrated in Figure 4-37).



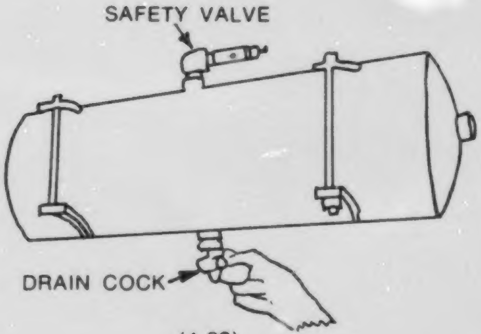
(4-37)

Courtesy of General Motors Corporation

DRAIN THE RESERVOIRS

Some further important service checks for air brake systems are:

All reservoirs have a drain cock that should be drained after each shift (Figure 4-38).



(4-38)

Courtesy of the Government of British Columbia Air Brake Manual

Draining reservoirs is usually an operator's job, but a mechanic may do it as part of a p.m. check. Draining is necessary because air from the atmosphere has moisture which condenses and settles in the reservoir. A small amount of oil will usually be present as well. This mixture of oil and water is milky white when drained. If an excessive amount of oil is present in the drainings, trouble may be indicated in the compressor.

CHECK BELT TENSION

If the compressor is a belt drive, check the belt tension.

1. Use a V-Belt Tension Gauge to check belt tension (Figure 4-39).

V-BELT TENSION GAUGE
T-9964

(4-39)

Courtesy of General Motors Corporation

2. Or, if a gauge is not available, place a straight edge across the two pulleys and depress the belt with your thumb. The slack should be approximately 1 inch ($2^1/_2$ cm).

REPLACING AIR LINES

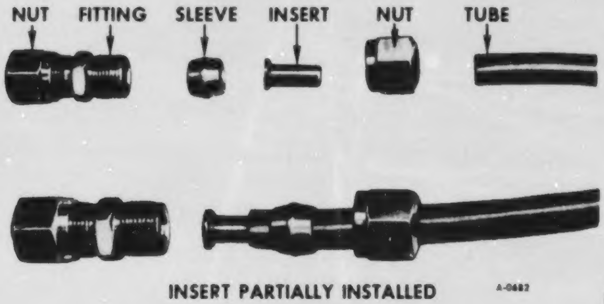
Air brake lines are either metal tubing, nylon tubing or flexible hose.

The metal lines are annealed copper tubing with a three piece compression fitting (flared fittings should not be used for air lines). When replacing metal lines the cut end should be free of burrs and the lines blown clear with compressed air; metal particles can ruin the seating surfaces of the control valves. Make sure when replacing any type of line that the new line is the same size as the one taken out.

Nylon tubing has replaced many lines that used to be metal. Nylon is flexible, durable, and weather resistant making it suitable for many air brake applications, such as connecting lines between stationary components and long lines that run the length of the frame rails. Nylon is not suitable, though, for use in areas where temperatures could exceed

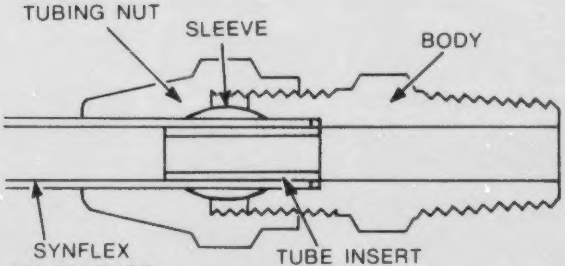
200°F (93°C) or for use between the vehicle frame and moveable axle housings where the brake chambers are located. Because nylon can be used only on certain lines, never replace a metal line with a nylon one unless it is in an approved nylon location. When a number of nylon lines run alongside one another, tape them together for added support and protection.

The fittings (Figure 4-40) for nylon tubing are easy to install, requiring no special tools. Simply cut the line to the required length and install the fitting. Avoid tight lines or lines that are longer than they have to be. Figure 4-41 shows a cut away of a nylon line connection.



(4-40) NYLON AIR LINE FITTINGS

Courtesy of General Motors Corporation



(4-41)

Courtesy of Bendix Corporation

Flexible hose, or more specifically, wire braid hose, is used for air lines between the brake chambers and the frame and axle housings, and for trailer connections. Flexible hose, like nylon tubing, has also replaced some lines that used to be metal. Wire braid hose is available in a variety of sizes, #4, #6, #8, etc.

When making up flexible hose, be sure the fittings are compatible with the hose. Follow the same make up procedures mentioned for hydraulic hoses with replaceable fittings:

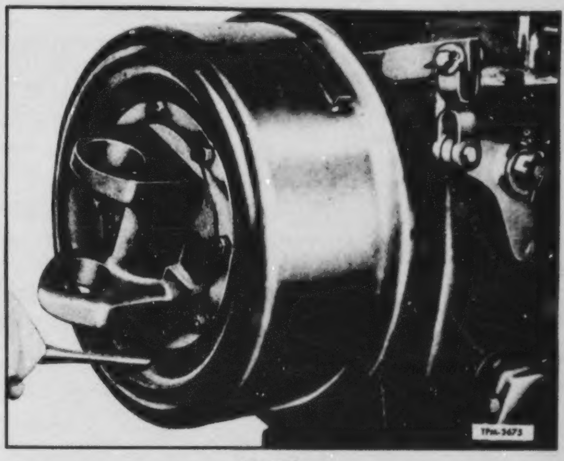
1. install the hose so that it lies naturally, without twist
2. guard hose that is near heat
3. support long lines

After any air line has been installed, carefully check the connections for leaks. One common way to look for a leak is to put soapy water on the connection and when the brakes are applied check for bubbles.

ADJUSTING PARKING BRAKES

Since parking brakes are mechanical and usually not too difficult to get at, they are generally easy to adjust. Check the service manual for the method of adjustment on any given type of parking brake. Below are two examples of adjustments on drive shaft parking brakes. Be sure not to adjust the brake too tightly because overheating can result.

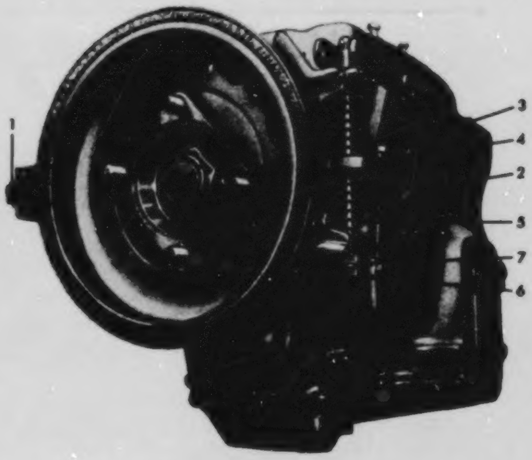
1. Internal expanding parking brake: adjust a star wheel through an access hole in the drum (Figure 4-42).



(4-42)

Courtesy of General Motors Corporation

2. External contracting band parking brake: three adjustments at points (1), (4) and (6) in Figure 4-43.



(4-43) PROPELLER SHAFT PARKING BRAKE (BAND TYPE)

1	Anchor Screw	5	Adjusting Bolt
2	Locating Bolt	6	Lock Nut
3	Lock Nut	7	Adjusting Nut
4	Adjusting Nut		

Courtesy of General Motors Corporation

A final word about brake work. Because they are so important to the safety of a vehicle, use extra care when working on or near brakes, no matter how minor the task may be. A service man must be certain that the brakes are safe.

QUESTIONS — BRAKE MAINTENANCE

1. What are the two methods of bleeding brakes?
   Which one is the most effective?
2. What is the most obvious indication of a need for brake adjustment?
3. To quick check a vacuum-assist power booster, put your foot on the brake pedal and start the engine. The pedal should:
   - (a) move up slightly
   - (b) go to the floor
   - (c) go spongy
   - (d) drop slightly
4. Adjustable anchors should be adjusted each time that the shoes are adjusted. True or False?
5. Briefly explain why brake adjustment is so important on air brakes.
6. Air brakes are properly adjusted if, when applied, the angle between the push rod and the slack adjuster is:
   - (a) 180°
   - (b) 35°
   - (c) 90°
   - (d) 70°
7. Air reservoirs should be drained:
   - (a) after every shift
   - (b) before every shift
   - (c) once a week
   - (d) all of the above are acceptable
8. What test must be made after installing or replacing any air line?
9. If hydraulic brake fluid is discolored the brake system should be ____________
   ________________________________.

ANSWERS — BRAKES

1. (c) Heat energy
2. coefficient of friction.
3. overloading the vehicle and braking at high speeds
4. standard hydraulic brakes, power-assisted hydraulic brakes, full air-brakes
5. (c) a confined fluid
6. When the force on the master cylinder piston is released, springs return the wheel cylinder piston to its non-applied position and in doing so push the oil back to the master cylinder.
7. Vacuum

   Air-over-oil

   Oil-over-oil
8. The multiplier vacuum-assist brake is frame mounted and the control valve is operated by pressure from the master cylinder. It is generally used by trucks.

   The integral vacuum-assist brake is firewall mounted and the control valve is operated directly by the foot pedal. It is used by automobiles and light trucks.
9. The two shoes on a duo-servo brake have a single anchor and they have an interrelated action against the drum. The two shoes on a non-servo brake have separate anchors and the shoes act independently against the drum.
10. (c) air cylinder or power cluster
11. cooled
12. Disc or rotor, caliper, hydraulic wheel-cylinder.
13. Power steering oil pressure.
14. (b) compressed air
15. (b) spring applied and air released
16. No. Brake fluid is a composite of glycerine, alcohol and performance additives.
17. Forcing fluid through the entire hydraulic system after working on it to remove the air.

ANSWERS — BRAKE MAINTENANCE

1. 1. Manual bleeding
   2. Pressure bleeding

   Pressure bleeding is the most effective.
2. Excessive pedal travel.
3. (d) drop slightly
4. False
5. The brake chambers have a specific volume and stroke, and once the maximum stroke has been reached, the brakes cannot be pumped up. Therefore, the stroke must be kept at a minimum.
6. (c) 90°
7. (a) after every shift
8. Check it for leaks.
9. flushed.

BRAKE TASKS

PREVENTIVE MAINTENANCE SERVICE ON BRAKES

SAFETY

Practice safety when working with brake systems by:

1. Chalking the wheels.
2. Applying the emergency brake before working on or near the vehicle.
3. Bleeding pressurized systems before disconnecting any hoses or removing any components.

HYDRAULIC BRAKES

Routine Maintenance Checks

1. Check the brake fluid reservoir and, if low, fill with the correct type of brake fluid.
2. Consulting the service manual, make brake adjustments to compensate for normal running wear.

AIR BRAKES

Daily and Routine Maintenance Check

Following procedures from the service manual:

1. Drain the reservoir.
2. Check the tension on the compressor drive belt and adjust if loose.
3. Clean the compressor air filter.
4. Make brake adjustments to compensate for normal running wear.
5. Start the engine and build up the air supply. Stop the engine, and check the system for air leaks, repairing any that are found.

VACUUM POWER-BRAKES

Routine Maintenance Check

1. To check the operation of vacuum power-brakes pump the brake pedal several times with the engine stopped, and then hold your foot on the pedal and start the engine. The brakes are working properly if the pedal moves down slightly when the engine is started.

AIR-OVER-OIL POWER BRAKES

Routine Maintenance Check

1. To check the operation of air-over-oil power brakes run the engine until the reservoir pressure is maximum, and then move the vehicle forward and apply the brakes. The brakes should respond quickly to stop the vehicle.

OIL-OVER-OIL POWER BRAKES

Routine Maintenance Check

1. To check the operation of oil-over-oil power brakes run the engine until the brake pressure gauge reads maximum, and then turn off the engine. The gauge pressure should remain up. Apply the brakes and the pressure should drop with each application.

EMERGENCY BRAKES

Routine Maintenance Check

Consulting the service manual, make minor adjustments on an emergency brake and lubricate the related linkages. The service will be done correctly if the emergency brake works easily and will hold the vehicle on an incline.

BLOCK

5

Power Trains

POWER TRAINS

BASIC FUNCTION OF POWER TRAINS

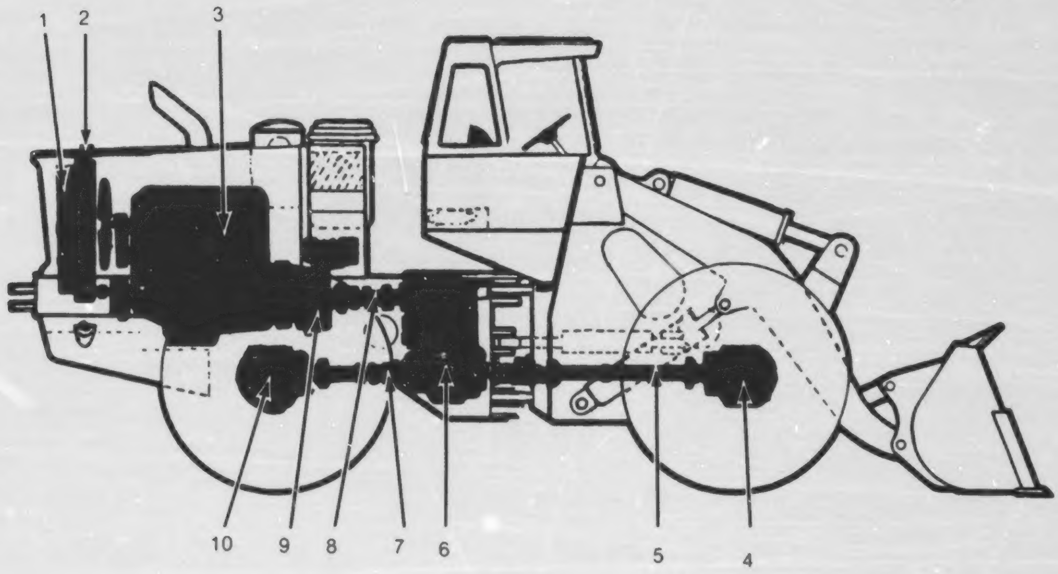
Power trains transmit power from the engine to the drive wheels or to the tracks. The four basic functions of power trains are:

- connect and disconnect power
- select speed and torque ratios
- provide a means of reversing the vehicle
- equalize power to the drive wheels for turning

To do these jobs, three main parts are needed:

1. clutch — to connect and disconnect power.
2. transmission — to select speeds and direction.
3. differential — to equalize power for turning

Other parts of power trains are final drives, torque converters, universal joints, drive shafts, axles and retarders. Power trains for a wheel loader and a crawler dozer are shown in Figure 5-1 and 5-2.

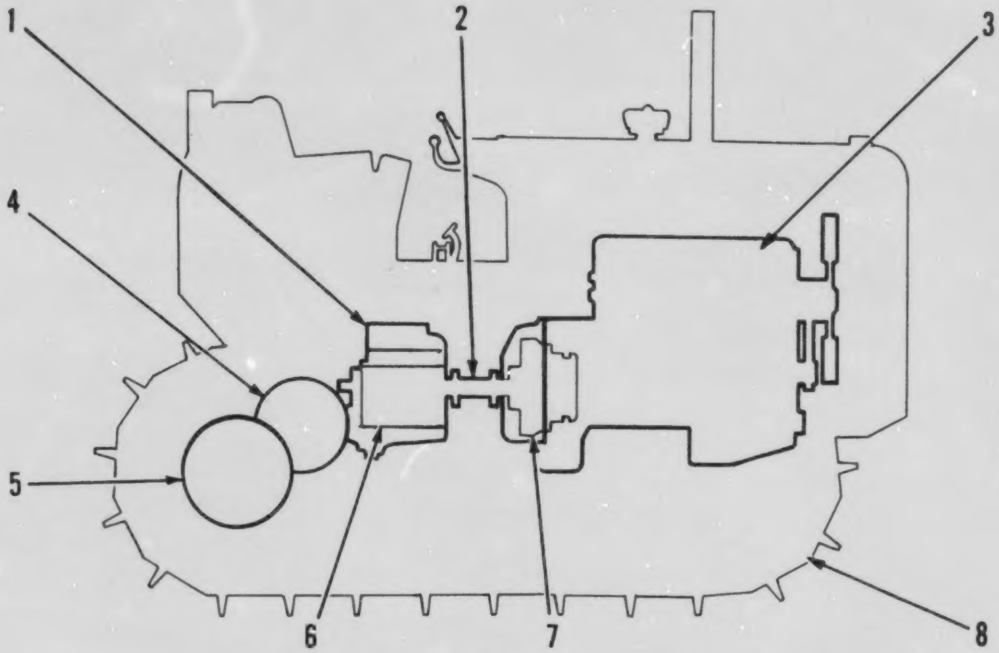


(5-1) WHEEL LOADER POWER TRAIN

Courtesy of International Harvester.

1	Oil Cooler	6	Transmission
2	Radiator	7	Rear Lower Drive Shaft
3	Engine	8	Upper Drive Shaft
4	Front Axle	9	Torque Converter
5	Front Drive Shaft	10	Rear Axle

General Arrangement



1—Transmission hydraulic controls. 2—Universal joint. 3—Diesel engine. 4—Steering clutches. 5—Final drive. 6—Range transmission. 7—Torque divider. 8—Track.

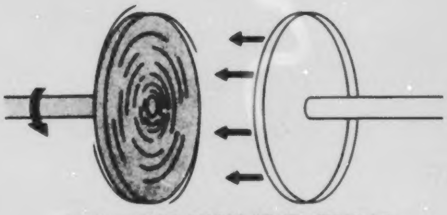
(5-2) CRAWLER DOZER POWER TRAIN

Courtesy of Caterpillar Tractor Co.

HOW A POWER TRAIN WORKS

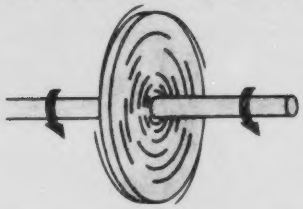
The first part of a power train is the clutch. The clutch's job is to disconnect the engine from the power train, allowing the engine to run while the machine is standing still. The clutch also engages this power to move the machine.

The principle of a disc clutch can be simply described. Think of a clutch as two discs, each on a shaft (Figure 5-3).



ONLY ONE DISK IS TURNING

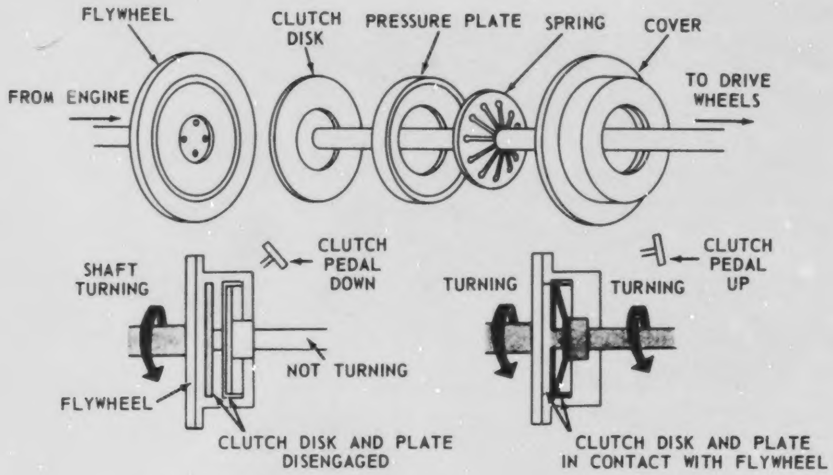
(5-3)



BOTH DISK ARE TURNING

Courtesy of John Deere Ltd.

As long as the discs are not touching, one can spin without affecting the other. But if the discs are moved together when one is spinning, the other begins to turn and almost instantly both shafts rotate as one unit. In an actual disc clutch (Figure 5-4) the discs are forced together by strong springs, and are separated by pushing down on the clutch pedal.


FLYWHEEL
CLUTCH DISK
PRESSURE PLATE
SPRING
COVER
FROM ENGINE
TO DRIVE WHEELS
SHAFT TURNING
CLUTCH PEDAL DOWN
NOT TURNING
FLYWHEEL
CLUTCH DISK AND PLATE DISENGAGED
TURNING
TURNING
CLUTCH PEDAL UP
CLUTCH DISK AND PLATE IN CONTACT WITH FLYWHEEL
X2020

CLUTCH DISENGAGED **CLUTCH ENGAGED**

(5-4) DISK CLUTCH IN OPERATION Courtesy of John Deere Ltd.

The next part of the power train is the transmission. The transmission's function is to change the speed of the drive wheels in relation to engine speed. Both automobiles and heavy duty vehicles require a transmission.

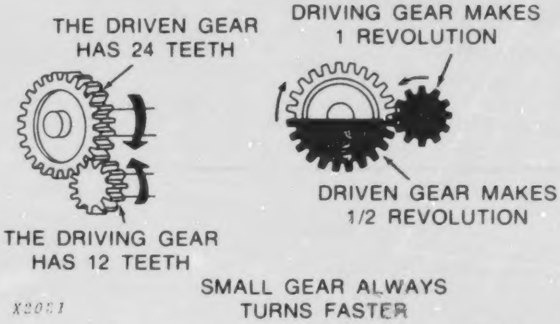
Automobiles need more turning force on the rear wheels to start moving than they need to cruise along a highway. The transmission provides this increased turning force and also allows the engine to accelerate. The acceleration is important because the engine does not develop very much power at low RPM's. When the car has picked up speed, the transmission increases the wheel to engine speed ratio until a direct drive between the engine and the wheels is achieved.

Tractors and other field machines require an even greater turning force or torque than an automobile to get traction and to pull heavy loads.

A transmission is a system of gears. In Figure 5-5 a small gear with 12 teeth drives a larger gear with 24 teeth. When the small gear has made one complete revolution, it has gone a distance equivalent to 12 teeth. The larger gear also turns through 12 teeth but this represents only one-half a revolution. Therefore, in this gear arrangement, the smaller gear makes two revolutions for every one of the larger. In other words, the smaller gear travels twice as fast as the larger.

In a transmission several combinations of smaller and larger gears are arranged so that the desired wheel to engine speed ratio can be selected.

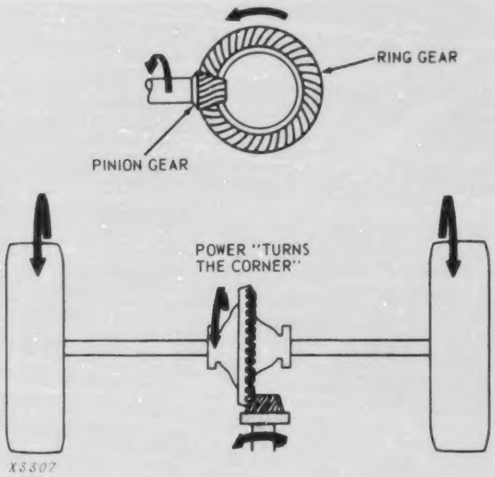
(5-5)


THE DRIVEN GEAR HAS 24 TEETH
DRIVING GEAR MAKES 1 REVOLUTION
DRIVEN GEAR MAKES 1/2 REVOLUTION
THE DRIVING GEAR HAS 12 TEETH
SMALL GEAR ALWAYS TURNS FASTER
X2021

HOW THE TRANSMISSION SELECTS A SPEED

Courtesy of John Deere Ltd.

After power passes through the transmission, it travels to the differential before getting to the rear axle and wheels. The differential, like the transmission, is a system of gears. The ring and pinion gears (Figure 5-6) allow the power to turn a 90° corner from the drive shaft, running lengthwise on the machine, to the drive axles running across it.



(5-6) RING GEAR AND PINION FOR REAR AXLE

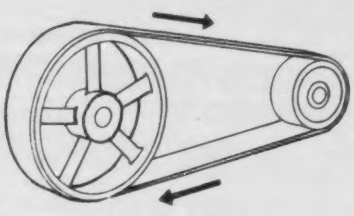
Courtesy of John Deere Ltd.

Not seen in Figure 5-6 are other differential gears that are needed to permit the wheels to travel at different speeds when cornering. These gears are discussed later in this section.

HOW POWER IS TRANSMITTED

Earlier it was shown that clutches use friction to transmit power, whereas transmissions and differentials use gears. A third way of transmitting power is by fluids, as in automatic drives. These three basic ways of transmitting power are illustrated in Figure 5-7.

1. Friction (Wheels and belts).



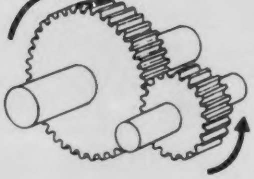
FRICTION

X3309

(5-7)

Courtesy of John Deere Ltd.

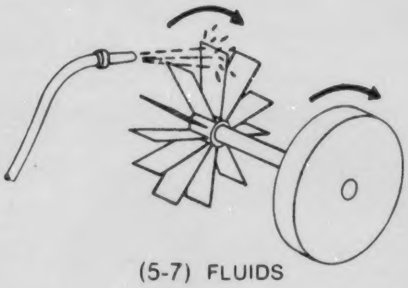
2. Gears in mesh



(5-7) GEARS

Courtesy of John Deere Ltd.

3. Fluids (the water wheel principle)



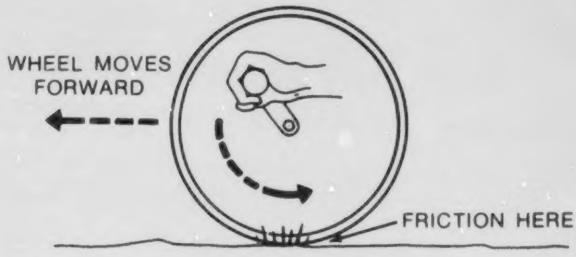
(5-7) FLUIDS

Courtesy of John Deere Ltd.

FRICTION DRIVES

Friction drive is the result of bringing together two surfaces made from materials that will transmit motion from one surface to the other. Slippage between the surfaces is a matter of design and for now will be assumed to be negligible. The engine clutch is a prime example of a friction drive.

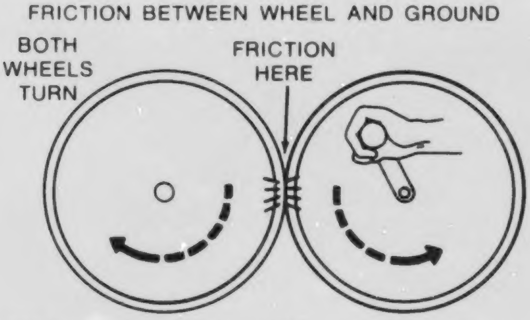
A simple form of useful friction is obtained when a rubber-tired wheel contacts the ground (Figure 5-8). The friction between the wheel and the ground causes the wheel to move forward when it is rotated by hand.



(5-8) FRICTION BETWEEN WHEEL AND GROUND

Courtesy of John Deere Ltd.

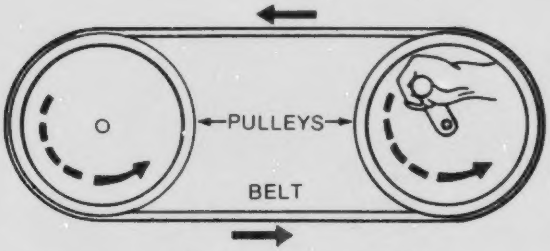
Another friction drive occurs when two wheels are suspended so that their outer circumferences touch (Figure 5-9). When a rotating force is applied to one wheel, the other will turn. Power is transmitted from one wheel to the other through their frictional contact. Note that the two wheels rotate in opposite directions.



FRICTION BETWEEN TWO WHEELS

(5-9) Courtesy of John Deere Ltd.

Add a belt to the two wheels and you create yet another type of friction drive (Figure 5-10).



(5-10) BELT FRICTION
Courtesy of John Deere Ltd.

When one wheel is turned, the frictional coupling of the belt transmits power to turn the other wheel. This arrangement permits the wheels to turn at some distance from one another. Belt drives are more efficient than just having the two wheels touch because the belt gives more wheel surface contact area.

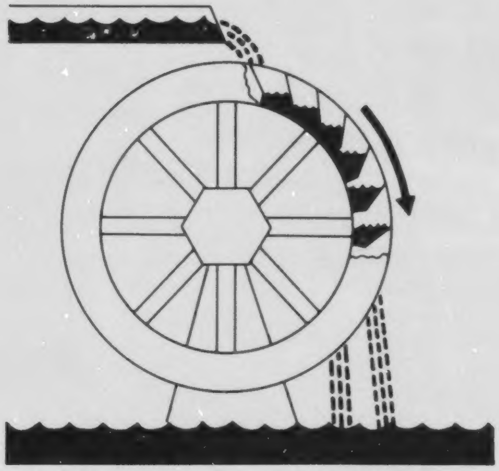
GEAR DRIVES

Gears are the most common way to transmit power. When two gears are in mesh, there is no slippage. For this reason gear drives are widely used for high-power applications.

A variation on gear drive is chain drive. The gears (sprockets) are not in mesh but are connected by a linked chain which also eliminates slippage.

FLUID DRIVES

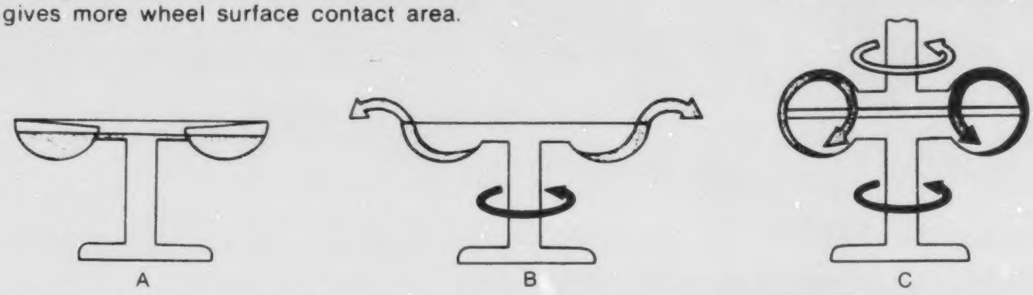
Fluid drive is both the oldest and most modern way of transmitting power. In the past water was used to turn a mill wheel to grind flour. (Figure 5-11).



(5-11) FLUID DRIVE IN WATER WHEEL
Courtesy of John Deere Ltd.

In modern times automatic drives use fluid to transmit power. Figure 5-12 illustrates the principles of fluid coupling in automatic drives.

Courtesy of John Deere Ltd.



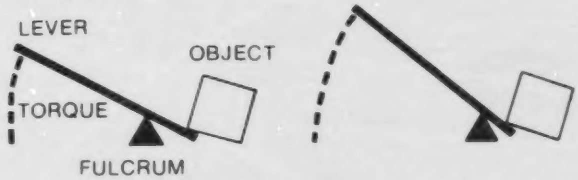
(5-12) FLUID COUPLING BETWEEN TWO SHAFTS

Picture A is a disc connected to a rotating shaft. The discs contain vanes which are filled with fluid. In B the disc is rotated at high speed and centrifugal force causes the fluid to move out as shown. In C a second disc is placed above and close to the first disc. Fluid now flows into the second disc as shown. The force of the fluid on the second disc will cause it to rotate in the same direction as the first, forming a fluid coupling which transmits power. When the discs are sealed and the fluid is under pressure, a solid coupling is formed. Fluid drives, such as torque converters and fluid clutches, operate according to this basic principle.

GEARS

The basic elements of almost all conventional power trains are gears. Gears are simply a means of applying twisting force, or torque, to rotating parts. The amount of torque obtained from a source of power is proportional to the distance from the center at which it is applied. (The larger the distance the greater the torque.)

The principle of leverage can be used to explain gear torque. A lever (Figure 5-13) has more torque as the distance from the fulcrum to the line of force increases (i.e., the radius of the applied force increases).



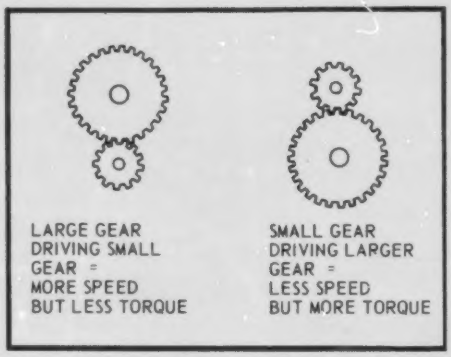
FULCRUM CLOSER TO OBJECT EQUALS
MORE TORQUE FOR LEVER
BUT LEVER MUST MOVE FARTHER

(5-13) HOW TORQUE VARIES WITH LEVERS

Courtesy of John Deere Ltd.

The radius of the applied force on the lever is analogous to the radius of the driven gear. The torque output of the gear increases as the radius of the gear increases. In other words, the larger the driven gear, the greater its torque.

Gear torque can't be discussed without also discussing gear speed. As a driven gear gets larger the distance that the teeth must travel for one revolution increases. Since this distance is greater, the gear will have less revolutions per minute, i.e., it will travel slower. Thus, as gear torque increases, there is a corresponding decrease in gear speed (Figure 5-14).



(5-14) HOW TORQUE VARIES WITH GEARS

Courtesy of John Deere Ltd.

The gears in a transmission are selected to give the operator a choice of both speed and torque.

Lower gear range = less speed but more torque.

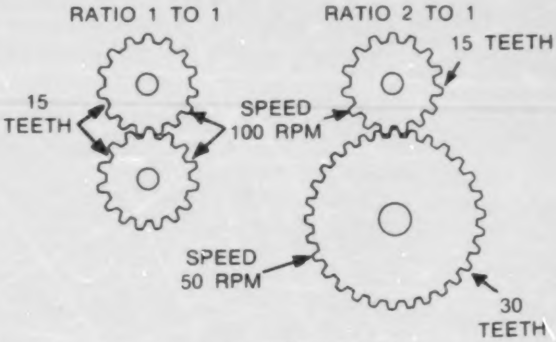
Higher gear range = less torque but more speed.

GEAR RATIO

Gear ratio is a measure of the changes in speed and torque in meshed gears. The formula for gear ratio is:

$$\text{gear ratio} = \frac{\text{number of teeth of driven gear}}{\text{number of teeth of drive gear}}$$

In Figure 5-15 the top gears are the drive gears.



(5-15) GEAR RATIOS

Courtesy of John Deere Ltd.

The gear ratio of the first set is $\frac{15}{15} = \frac{1}{1}$ or 1:1 (read: ratio of 1 to 1). A gear ratio of 1:1 means that both gears turn at the same speed with the same torque. The gear ratio of the second set is $\frac{30}{15} = \frac{2}{1}$ or 2:1 which means that the drive gear travels twice as fast as the larger driven gear, but that the driven gear has two times more torque.

Consider another example: a 10 tooth gear drives a 60 tooth gear. The gear ratio would be:

$$\frac{\text{driven gear}}{\text{drive gear}} = \frac{60}{10} = \frac{6}{1} \text{ or } 6:1$$

The smaller drive gear travels six times as fast as the larger driven gear, but the driven gear has six times more torque. These three examples of gear ratios demonstrate the law of gear operation that states: any reduction in gear speed gives an equal increase in gear torque.

Further information on gear ratio and torque can be found in the first part of Chapter 47, "Gears", in **Automotive Mechanics, Seventh Edition.**

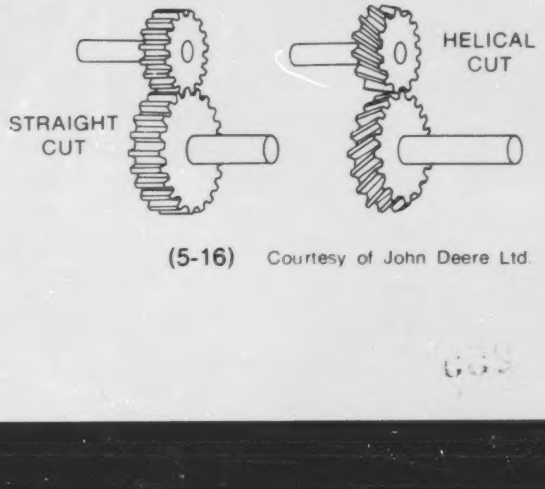
TYPES OF GEARS

Gears are normally used to transmit torque from one shaft to another. The shafts may be in line or they may be parallel or be at an angle to one another.

Gears that mesh must have teeth of the same size and design, and must have at least one pair of teeth engaged at all times. Some gear teeth are designed to have contact between more than one pair of teeth. Gears are normally classified by:

1. Type of teeth.
2. Surface angle on which teeth are cut.

Figure 5-16 shows two categories of gear teeth.

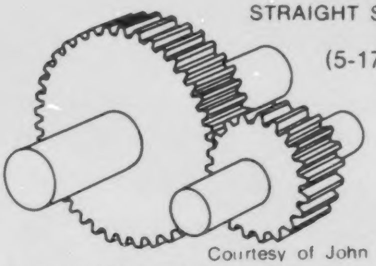


(5-16) Courtesy of John Deere Ltd.

There are many different types of gears, each having its own application. The four most common you will encounter at this stage of training are:

1. **Straight Spur Gears** (Figure 5-17) — These gears have straight teeth cut parallel to the axis of rotation. Normally, mating gears have two pairs of teeth engaged at all times. These gears are noisy and are used mainly for slow speeds. At higher speeds spur gears tend to vibrate.

   Uses: Straight spur gears are used in devices such as hand or powered winches. Sliding gear transmissions also use spur gears for speed changes because the shape of the teeth allows a sliding gear to easily mesh and demesh with stationary gears.

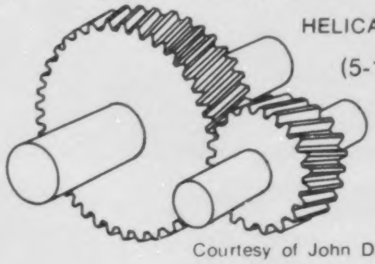


STRAIGHT SPUR (5-17)

Courtesy of John Deere Ltd.

2. **Helical Spur Gears** (Figure 5-17) — The teeth of helical spur gears are cut obliquely across the perimeter of the gear instead of straight across. Engagement between two teeth starts at the tooth tip of one gear and rolls down the teeth to the trailing edge. This angular contact tends to cause side thrusts which the bearings must absorb. However, helical spur gears are quieter in operation, and have greater strength and durability than straight spur gears because their contacting teeth are longer.

   Uses: Helical spur gears are widely used in machine transmissions because they are quieter at high speeds and are durable.

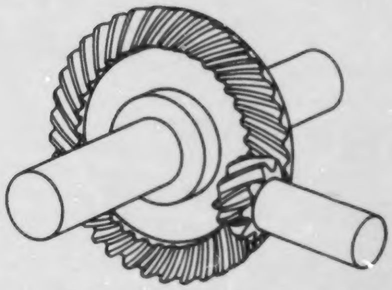


HELICAL SPUR (5-17)

Courtesy of John Deere Ltd.

3. **Spiral Bevel Gears** (Figure 5-17) — These gears were developed for use where high speed and strength are required while changing the angle of power flow. Their teeth are cut obliquely on the angular faces of the gears. The angle is determined by the angle between the two shafts.

Uses: Farm and industrial machines use spiral bevel gears in ring and pinion gear sets at the drive axles. The ring and pinion gears not only change the angle of power flow, but also reduce speed and increase the turning force.

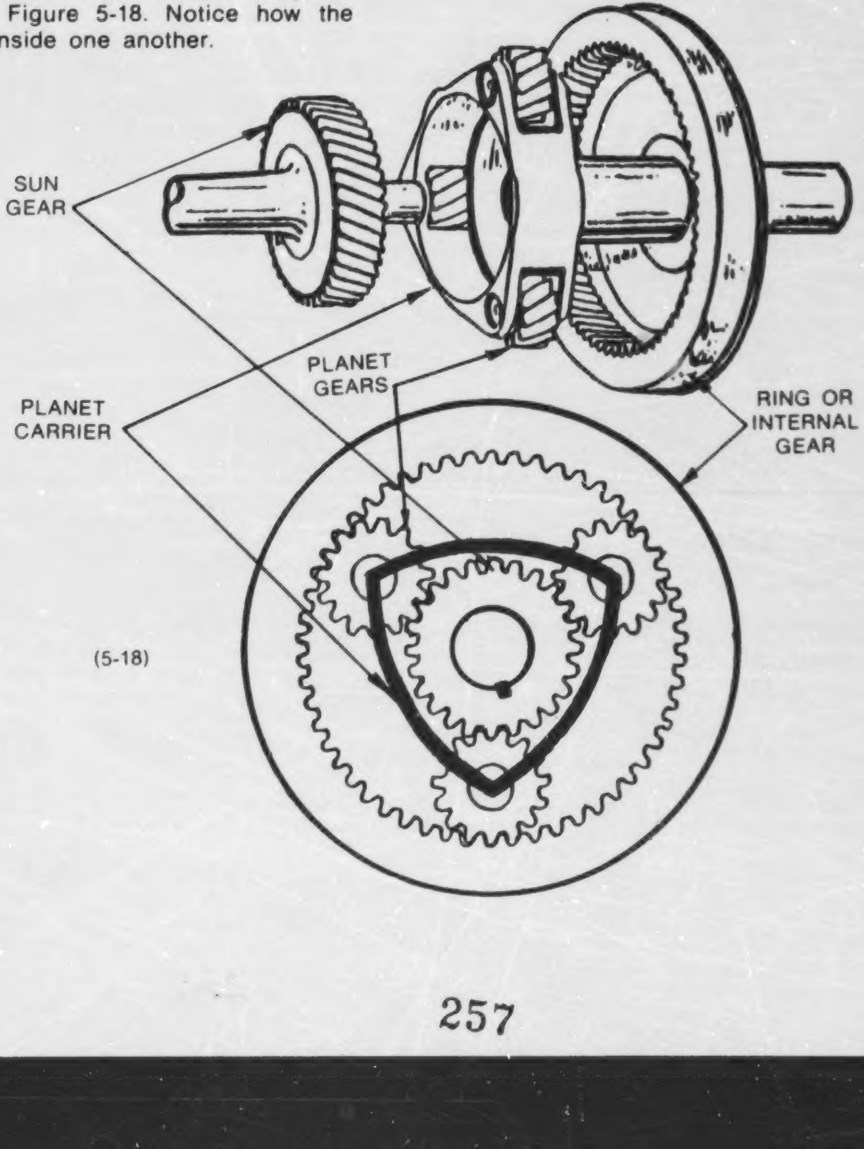


(5-17) SPIRAL BEVEL
Courtesy of John Deere Ltd

4. **Planetary Gears** — A planetary gear is a set of three gears:

— Ring or Internal Gear
— Planet pinions and carrier
— Sun Gear

A side and end view of a planetary are shown in Figure 5-18. Notice how the gears fit inside one another.



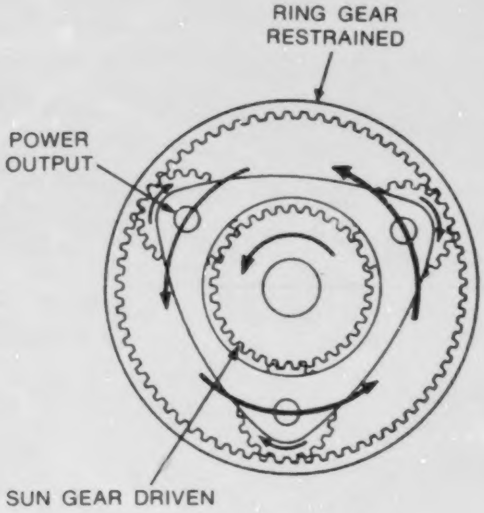
(5-18)

The ring gear has teeth on its inner diameter which mesh with the teeth on the planet pinions. The planet pinions are held by the carrier and in turn mesh with the sun gear. The type of teeth used on these gears may be straight spur or helical spur (as in the diagram).

To obtain a power flow through a planetary gear set:

(a) Hold one gear by a brake or clutch, or by solidly anchoring it.
(b) Drive one gear.
(c) The third gear will be driven (power output).

These three gears all remain in constant mesh and give many speed changes and torque outputs depending on which gear is held and which gear is powered. It is possible to get four forward speed ratios, two reverse speed ratios, as well as direct drive and neutral from a planetary gear set. However, on any given planetary only one or two ratios would be used. A common combination of planetary gears is illustrated in Figure 5-19. The sun gear is driven and the ring gear held, causing the planet pinions and thus the carrier to walk around the inside of the stationary ring gear. The result is a speed reduction to the carrier. This gear combination is often used to give a gear reduction in a final drive.



(5-19)

Courtesy of John Deeere Ltd.

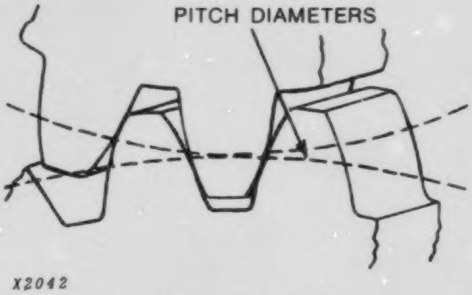
Two main advantages of planetaries are:

(a) the load is spread over several gears reducing the stress and wear on any one gear.
(b) a high reduction can be obtained within a limited space.

Planetaries are very common gear sets found on both track and wheeled machines. Transmissions, drive axles, final drives, and wheel reductions for large machines are just a few areas where planetary gear sets are used.

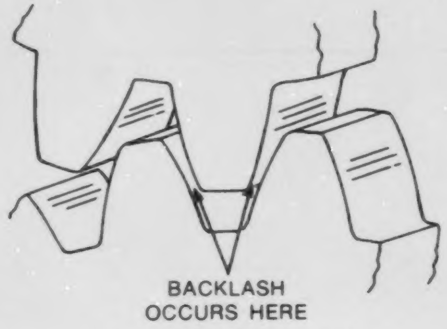
BACKLASH IN GEARS

Backlash is the clearance or play between two gears in mesh. Too much backlash can be caused by worn gear teeth, by an improper meshing of teeth or by bearings which do not support the gears properly. Extreme backlash can result in severe impact on the gear teeth from a sudden stop or reverse of the gears. Figure 5-20 shows both normal gear mesh, and gear mesh that permits too much backlash.



NORMAL GEAR MESH

(5-20) BACKLASH IN GEARS



TOO MUCH BACKLASH

Courtesy of John Deere Ltd.

On normal gears the clearance of the teeth at the pitch diameters is very small. On worn gears the clearance is widened, and the resulting backlash causes greater movement and impact which can bounce the gears or, at worst, break them.

POWER TRAIN COMPONENTS

CLUTCHES

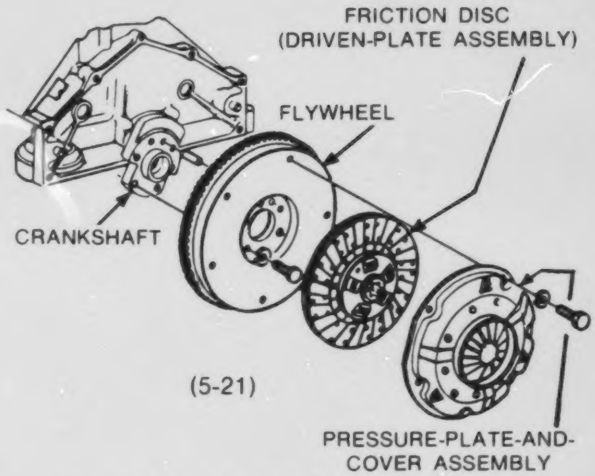
At this level of training the clutches you are most likely to come into contact with are:

1. Disc or plate clutches —
   - single disc, double disc — engine clutches
   - multi disc — used in crawler steering and power shift transmissions
2. Jaw clutches — used in shovel steering.

SINGLE AND DOUBLE DISC ENGINE CLUTCHES

The purpose of the engine clutch is to connect and disconnect the power flow from the engine to the transmission so that the driver can shift gears to take up the load gradually. The clutch also allows the vehicle to stop without stalling the engine.

A clutch uses friction to transmit power. A single plate clutch consists of a flywheel connected to the crankshaft, a friction disc splined to the transmission shaft and a pressure plate assembly bolted to the flywheel (Figure 5-21).


FRICTION DISC
(DRIVEN-PLATE ASSEMBLY)
FLYWHEEL
CRANKSHAFT
PRESSURE-PLATE-AND-
COVER ASSEMBLY

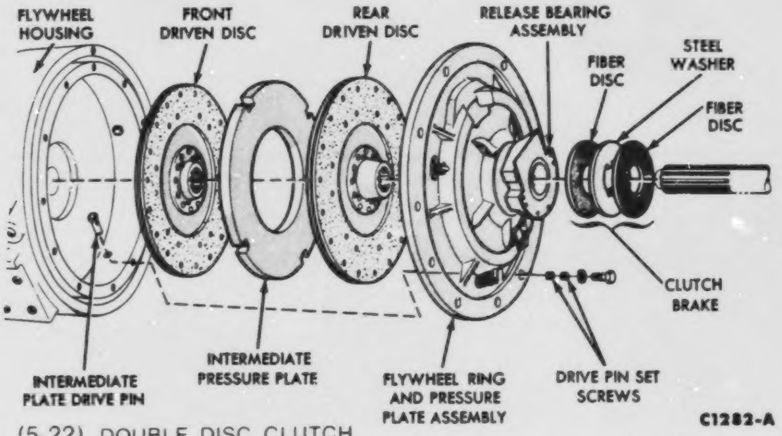
(5-21)

Courtesy of General Motors Corporation

When a clutch is engaged, the pressure plate squeezes the clutch disc against the flywheel causing the whole assembly to turn as one. When disengaged, the pressure plate draws back from the clutch disc interrupting the flow of power from the engine to the transmission.

The single plate clutch is generally used on automobiles and on light trucks and industrial vehicles.

A double disc clutch (Figure 5-22) has an extra friction disc and pressure plate. This second pressure plate is slotted into the flywheel and it presses against the extra friction disc. Thus more friction surface is obtained within the same clutch diameter, making a stronger clutch. Double disc clutches are used on large trucks with high horsepower engines.


FLYWHEEL
HOUSING
FRONT
DRIVEN DISC
REAR
DRIVEN DISC
RELEASE BEARING
ASSEMBLY
FIBER
DISC
STEEL
WASHER
FIBER
DISC
CLUTCH
BRAKE
INTERMEDIATE
PLATE DRIVE PIN
INTERMEDIATE
PRESSURE PLATE
FLYWHEEL RING
AND PRESSURE
PLATE ASSEMBLY
DRIVE PIN SET
SCREWS
C1282-A

(5-22) DOUBLE DISC CLUTCH

Courtesy of Ford Motor Co.

Both single and double disc clutches require adjustment to compensate for running wear.

MULTI DISC CLUTCHES

Multi disc clutches are used for steering on crawler dozers and loaders. They are also used as clutch packs in both power shift transmissions and winches. Their main advantage is a high holding capacity for their limited size.

A multi disc clutch consists of a set of internally and externally splined discs. The clutch is assembled with the discs placed alternately, one lined, internally splined disc and one unlined, steel externally splined disc (the order can be reversed).

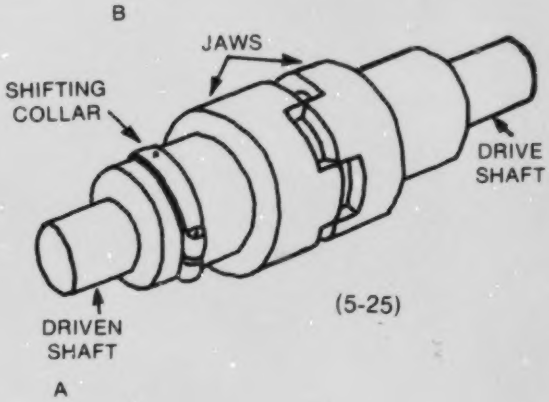
The internally splined discs fit over a hub and the externally splined discs fit into a drum. The discs are engaged and disengaged by one of two methods:

1. spring applied and hydraulically released, or
2. hydraulically applied and spring released.

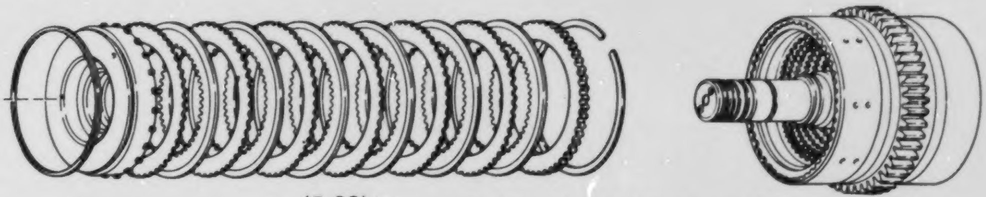
Figure 5-23 shows an exploded view of a multi disc clutch or clutch pack. Note the alternate arrangement of internally and externally splined discs.

Jaw Clutches

A jaw clutch (Figure 5-25) is the simplest of all clutches, consisting of two toothed jaws facing one another, one jaw fixed to a drive shaft the other to a driven shaft. When engaged the two shafts act as one; when disengaged each shaft can turn independently of the other. There is no friction involved with a jaw clutch; it is either engaged or disengaged.



(5-25)

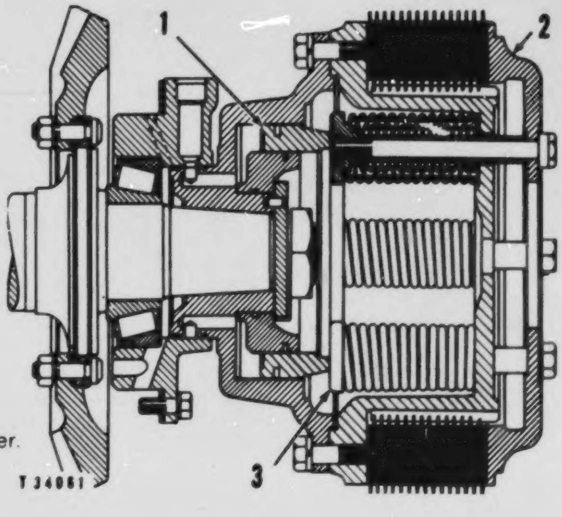


(5-23)

Courtesy of Clarke Equipment Co.

Clutch packs generally run in oil and therefore must use a type of lining material not affected by oil. Unlike single and double disc engine clutches, clutch packs are not adjustable.

Figure 5-24 shows a steering clutch with the outer drum removed. This assembly is spring applied and hydraulically released.



(5-24)

STEERING CLUTCH OPERATION

1—Piston. 2—Pressure plate. 3—Retainer.

Courtesy of Caterpillar Tractor Co.

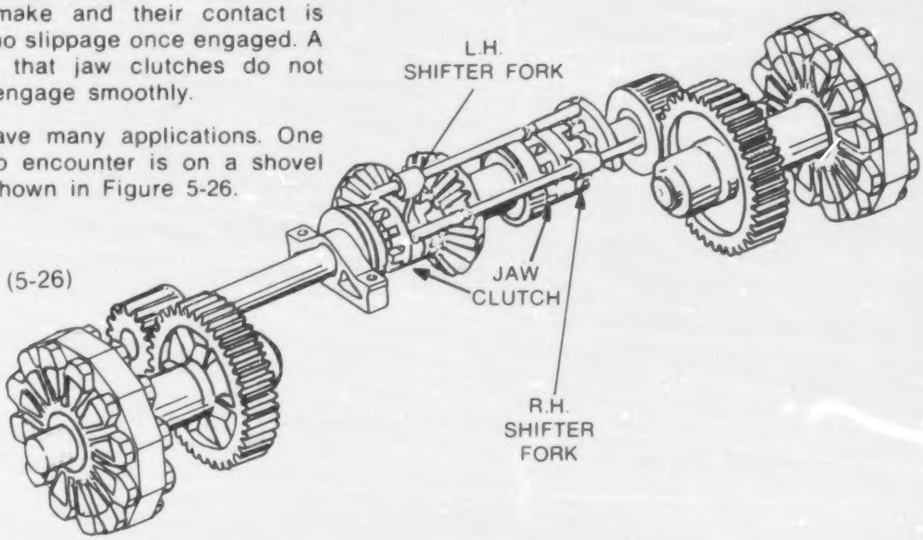
The driven jaw has a groove cut on its circumference for a shift fork to ride in. The shift fork pulls the jaw back to disengage the clutch and pushes it forward to engage the clutch. Obviously jaw clutches have to be engaged or disengaged when the machine is stopped and the power off.

The advantages of jaw clutches are that they are cheap to make and their contact is positive having no slippage once engaged. A disadvantage is that jaw clutches do not engage and disengage smoothly.

Jaw clutches have many applications. One you are likely to encounter is on a shovel drive, such as shown in Figure 5-26.

Courtesy of Harnischfeger Corporation, P&H

(5-26)



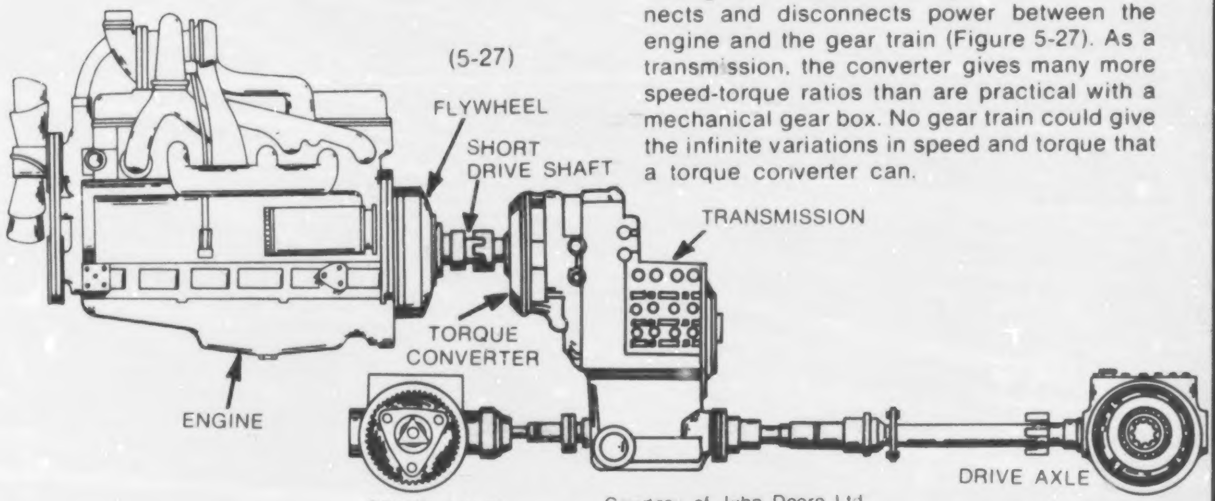
Jaw clutches need no adjustments. Their only requirement is that they be engaged fully.

TORQUE CONVERTERS

A torque converter is an automatic drive using fluids driven at high speeds and low pressure to transmit power from the engine. A transmission (i.e., a gear train) is combined with a torque converter to give extra speed ranges.

Acting as a clutch, the torque converter connects and disconnects power between the engine and the gear train (Figure 5-27). As a transmission, the converter gives many more speed-torque ratios than are practical with a mechanical gear box. No gear train could give the infinite variations in speed and torque that a torque converter can.

(5-27)

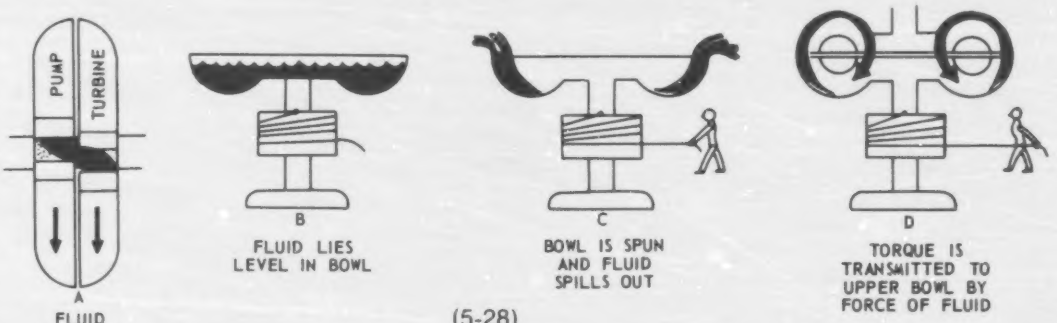


Courtesy of John Deere Ltd

TORQUE CONVERTER OPERATION

To understand how a torque converter works, first look at a basic fluid coupling. Inside an oil-filled housing are two parts: the driving half, or pump; and the driven half, or turbine.

Courtesy of John Deere Ltd.



A FLUID COUPLING

B FLUID LIES LEVEL IN BOWL

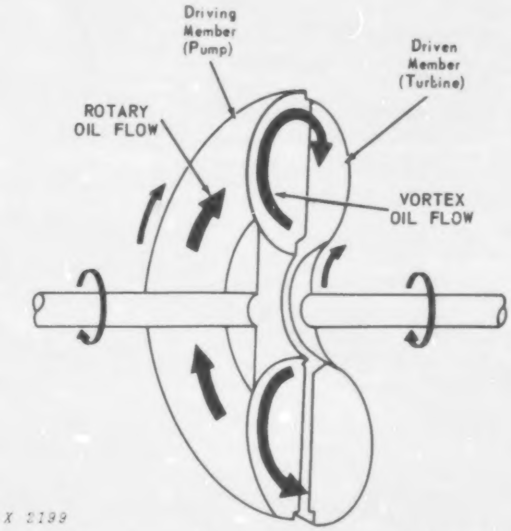
C BOWL IS SPUN AND FLUID SPILLS OUT

D TORQUE IS TRANSMITTED TO UPPER BOWL BY FORCE OF FLUID

(5-28)

As the pump is turned by the engine, centrifugal force causes oil to be forced radially outward and because the housing is curved the oil crosses over and strikes the vanes of the turbine causing the turbine to rotate in the same direction. Thus the power is coupled.

Two types of flow are produced in the revolving coupling (Figure 5-29). The circular flow of oil between the pump and turbine is called vortex flow. The flow around the pump and turbine that forms the coupling is called rotary flow.



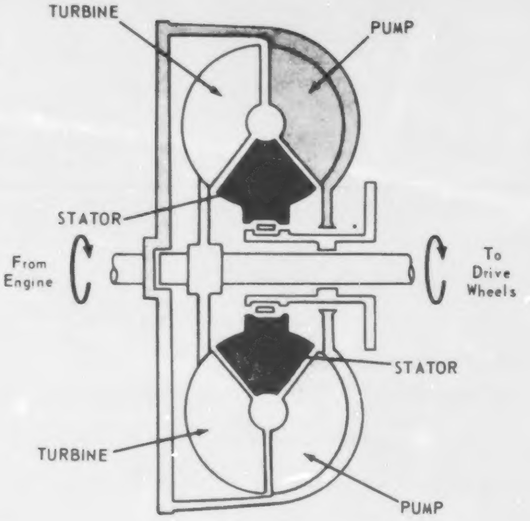
(5-29) VORTEX AND ROTARY FLOW IN A FLUID COUPLING

Courtesy of John Deere Ltd.

The combined action of the two oil flows will transmit torque but not increase it. Here is where the torque converter goes beyond the basic fluid coupling: the converter can multiply torque.

A torque converter (Figure 5-30) looks much like the fluid coupling above. The main difference is that the converter has, in addition to the driving pump and the driven turbine, a third member: a wheel of blades or vanes called a stator. The stator is mounted on a one way clutch. When the turbine is slow or stopped the stator wheel is stationary. In this position the stator vanes change the direction of oil flow after it has gone through the turbine and sends the flow back to the pump. The velocity of this returned flow is added to the velocity already existing in the pump. Thus, the pump velocity or output is increased. In this way the converter multiplies the torque.

Torque is increased as long as the turbine is turning slower than the pump. This occurs when the machine first starts to move. But as the machine speeds up, the turbine, which is directly splined to the transmission, also speeds up, causing the vortex flow of oil in the converter to decrease and the rotary flow to increase. As the turbine approaches pump speed, the stator free-wheels (in the same direction) and there is no longer a torque increase. Total rotary flow has been reached. The torque converter now acts as a single fluid coupling sending the same torque it receives onto the drive wheels.



(5-30) TORQUE CONVERTER

Courtesy of John Deere Ltd.

The torque converter is able to automatically, reduce or increase torque in infinitely small steps to match the needs of the machine and its driver. The converter has the same effect as shifting speeds in a gear transmission except that it is done smoothly and automatically while "on the go".

The above is only a basic explanation of how a torque converter works.

Many variations of converters are made to meet the demands of different machines.

STANDARD MECHANICAL TRANSMISSIONS

A mechanical transmission is a train of gears that transfers and adapts the engine power to the drive wheels of the machine. Usually the transmission is located to the rear of the engine and clutch, and in front of the differential or ring gear.

The transmission does two jobs:

- — selects speed-torque ratios
- — reverses the direction of the machine

For information on the operation of a basic transmission, read pages 457 to 461 (Chapter 47) in **Automotive Mechanics, Seventh Edition.**

TRANSMISSION CHARACTERISTICS

There are a number of mechanical transmissions. The types can be classified according to the:

- — Number of speeds
- — Number of countershafts
- — Location and number of transmissions used (there are main transmissions, auxiliary transmissions and transfer cases).

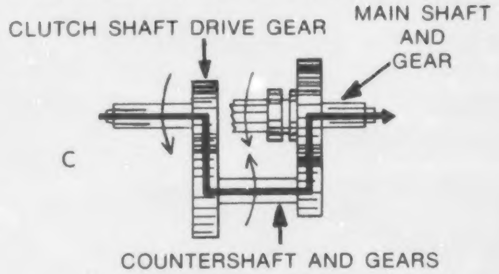
1. The number of transmission(s) speeds will depend on the size of the vehicle and the kind of work it does.

   Light duty machines may have three or four speeds whereas heavy duty machines may use one or two transmissions that give 15 or more speeds.

2. In the past transmissions had single countershafts and this design is still used on automobile and light trucks. However, many heavy duty vehicles now have transmissions with two or even three countershafts.

   The advantage of the multi-countershaft design is that the torque is divided evenly over two or more shafts. Dividing the torque reduces the load on the gears, shafts and bearings, thereby allowing the overall size and weight of the transmission to be reduced.

   Figure 5-31 shows power flow through a single countershaft transmission. This is a simplified figure; an actual transmission would have many more gears.

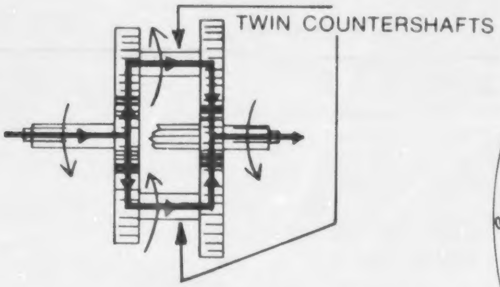


(5-31)

Courtesy of Eaton Corportion

The clutch shaft drive gear turns the countershaft gears; the countershaft gears turn the mainshaft gears.

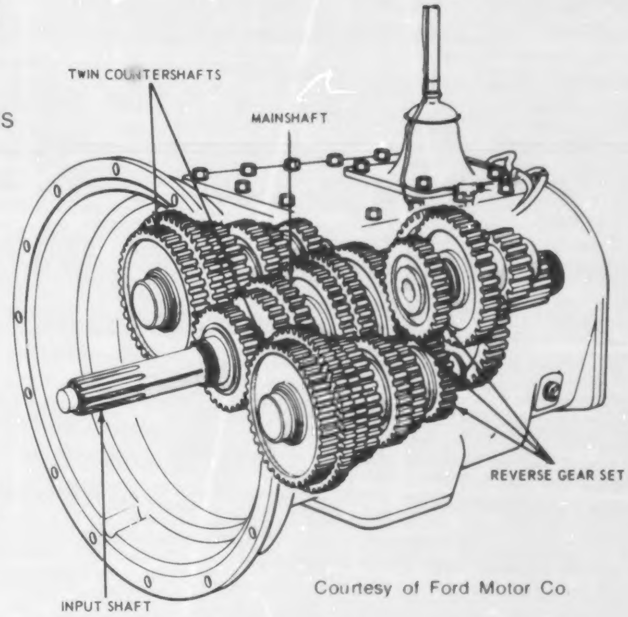
Figure 5-32 shows the power flow through a twin countershaft transmission. In this transmission the clutch shaft drive gear turns two countershafts.


TWIN COUNTERSHAFTS

(5-32)

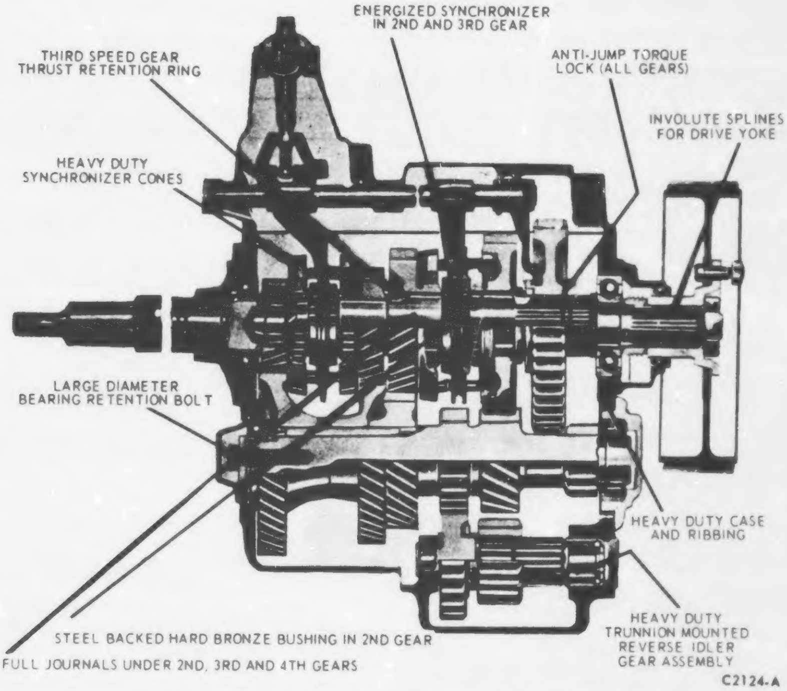
Courtesy of Eaton Corporation

Figure 5-33 gives more detailed views of single and twin countershaft transmissions.


TWIN COUNTERSHAFTS
MAINSHAFT
REVERSE GEAR SET
INPUT SHAFT

Courtesy of Ford Motor Co.

(5-33) TWIN COUNTERSHAFT TRANSMISSION


ENERGIZED SYNCHRONIZER IN 2ND AND 3RD GEAR
THIRD SPEED GEAR THRUST RETENTION RING
ANTI-JUMP TORQUE LOCK (ALL GEARS)
INVOLUTE SPLINES FOR DRIVE YOKE
HEAVY DUTY SYNCHRONIZER CONES
LARGE DIAMETER BEARING RETENTION BOLT
HEAVY DUTY CASE AND RIBBING
HEAVY DUTY TRUNNION MOUNTED REVERSE IDLER GEAR ASSEMBLY
STEEL BACKED HARD BRONZE BUSHING IN 2ND GEAR
FULL JOURNALS UNDER 2ND, 3RD AND 4TH GEARS
C2124-A

(5-33) SINGLE COUNTERSHAFT TRANSMISSION

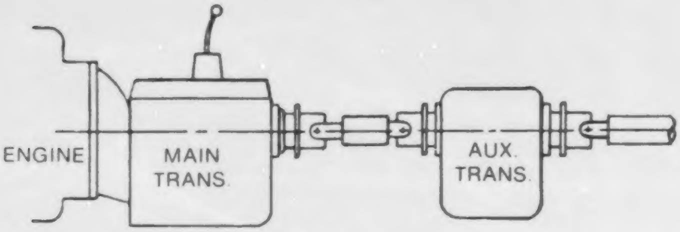
Courtesy of Ford Motor Co.

3. Location and number of transmissions used:

   Large vehicles require multiple speeds, and may couple an auxiliary three or four speed transmission to the main transmission. For example, coupling a four speed auxiliary to a five speed main transmission will give a total of 20 speeds.

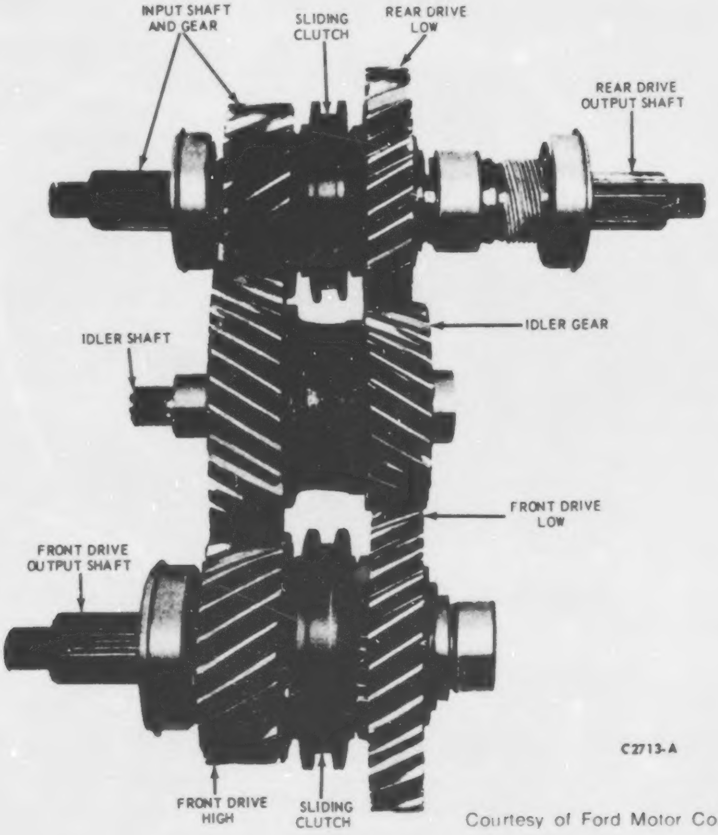
   The main and auxiliary transmission shown in Figure 5-34 is a multi-countershaft design which allows both transmissions to be coupled as one.

A transfer case can also be coupled to a main transmission. A transfer case is used for vehicles with four wheel drive providing power flow to the front drive axle and giving a super low gear for off-highway work. The idler or transfer gear lowers the power from the main driveshaft to the front shaft. In Figure 5-35 a transfer gear is shown with the case removed.


ENGINE
MAIN TRANS.
AUX. TRANS.

(5-34)

Courtesy of Eaton Corporation


INPUT SHAFT AND GEAR
SLIDING CLUTCH
REAR DRIVE LOW
REAR DRIVE OUTPUT SHAFT
IDLER GEAR
IDLER SHAFT
FRONT DRIVE LOW
FRONT DRIVE OUTPUT SHAFT
C2713-A
FRONT DRIVE HIGH
SLIDING CLUTCH

Courtesy of Ford Motor Co.

(5-35)

POWER SHIFT TRANSMISSIONS

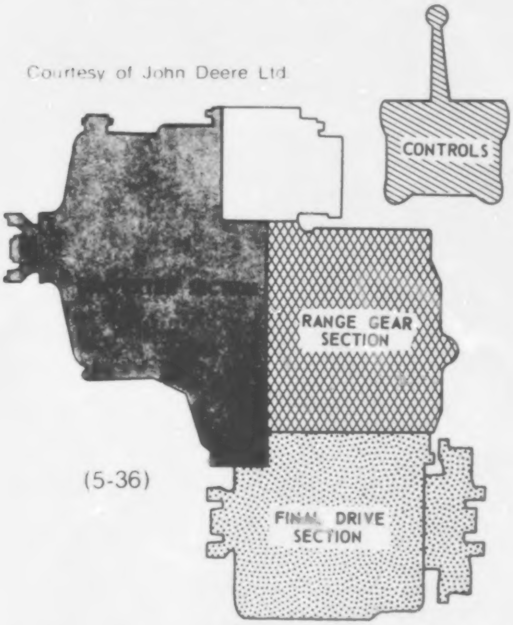
Power shift transmissions are one of the most important inventions in modern machinery. Most heavy duty equipment made today has a power shift transmission.

A power shift transmission in a heavy duty vehicle performs a job similar to an automatic transmission in an automobile. Like an automatic transmission, a power shift allows shifting without releasing an engine clutch. Unlike automatic transmissions however, shifts for speeds are not made automatically, but are made by the operator.

Power shift transmissions can be grouped into two general types: (1) planetary gear type and (2) spur gears on parallel shafts. Regardless of the type, power shifts have four major components (Figure 5-36):

— converter
— range gear section
— final drive section (on some)
— hydraulic control system

Courtesy of John Deere Ltd



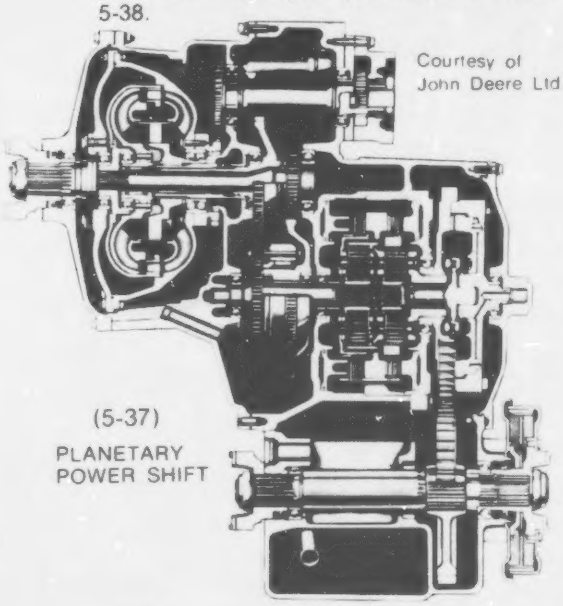
(5-36)

1. The **converter** replaces the clutch of the manual transmission, coupling the engine and transmission together. There are many variations in the size and torque output of converters.
2. The **range gear section** provides speed and direction changes. It uses hydraulically applied clutch packs to alter the gear ratios of planetary gear sets or the ratios of spur gears on parallel shafts.
3. If a **final drive** section is used, its purpose is to transfer the power flow down to a lower level where it can then travel out to the front and rear wheel drive. The final drive provides a reduction in some cases. However, in others where no reduction is made, the input final drive gear is on a one to one ratio with the output gear.
4. The **hydraulic control system** gives life to the powershift assembly. It uses oil to:

— lubricate and cool all the parts
— engage the clutch packs
— drive the turbine in the converter

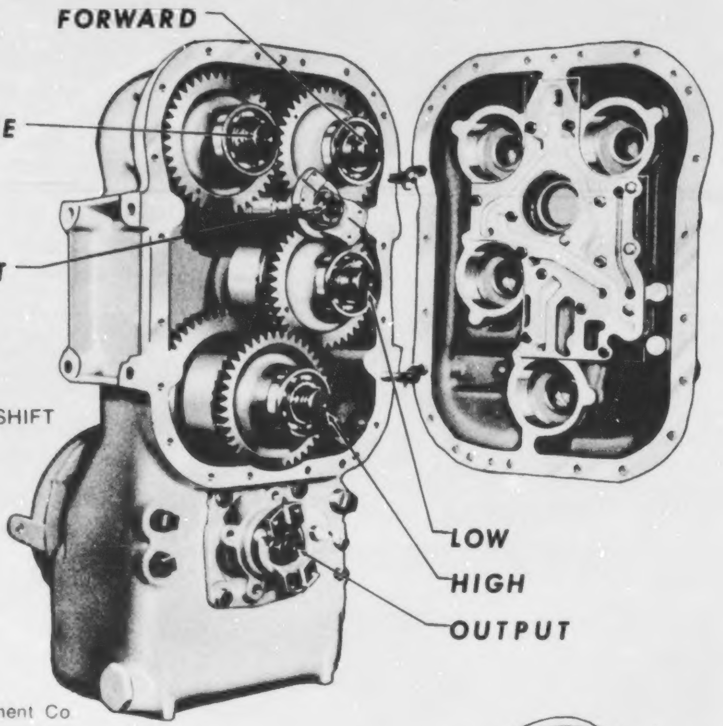
The transmission housing generally serves as the oil reservoir. A converter driven pump picks up oil from the housing and filters it. Then the pump pressurizes the system. The pressurized oil charges the converter, and circulates throughout the transmission, lubricating all the critical areas. A control valve directs the oil to the various clutch packs to give the correct combination of speed and direction required by the operator. An oil cooler is an essential part of the hydraulic control system. Oil from the converter is circulated through the cooler and returned to the transmission. The cooler prevents the oil from over-heating and destroying the assembly.

A planetary powershift is shown in Figure 5-37, and a spur gear powershift in Figure 5-38.



Courtesy of John Deere Ltd

(5-37)
PLANETARY POWER SHIFT


FORWARD
REVERSE
INPUT
LOW
HIGH
OUTPUT

(5-38)
SPUR GEAR POWER SHIFT

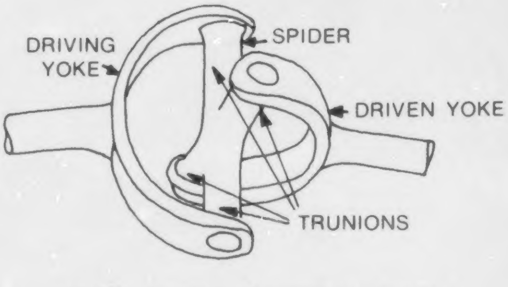
Courtesy of Clarke Equipment Co

DRIVE LINES

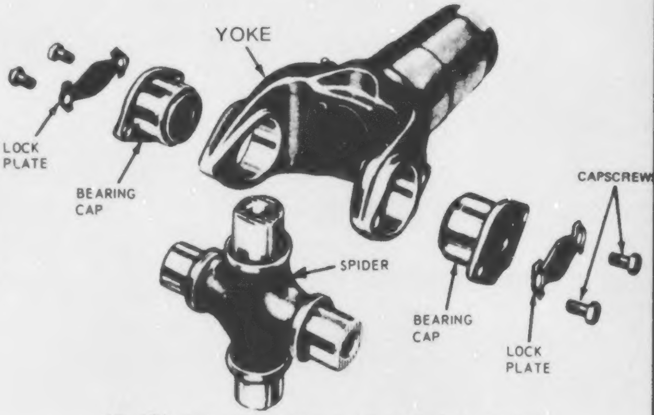
The drive line transmits the driving torque from the transmission(s) to the drive axle(s). A drive line may have one drive shaft or it may have multiple shafts, depending on the size and drive axle arrangement. Each drive shaft has a universal joint at either end which allows the shaft to hinge. Being able to hinge makes the shaft flexible and enables it to transmit power at an angle. A universal joint is a double hinged joint consisting of:

1. two "Y" shaped members called "yokes".
2. a cross shaped member called the "spider".
3. Four arms on the spider called "trunions".
4. bearing caps and needle bearings installed on the ends of the trunions.

Two illustrations of universal joints are given in Figures 5-39 and 5-40. The first is a simplified view. The second is more detailed (note that only one yoke is shown).


DRIVING YOKE
SPIDER
DRIVEN YOKE
TRUNIONS

(5-39) SIMPLE UNIVERSAL JOINT

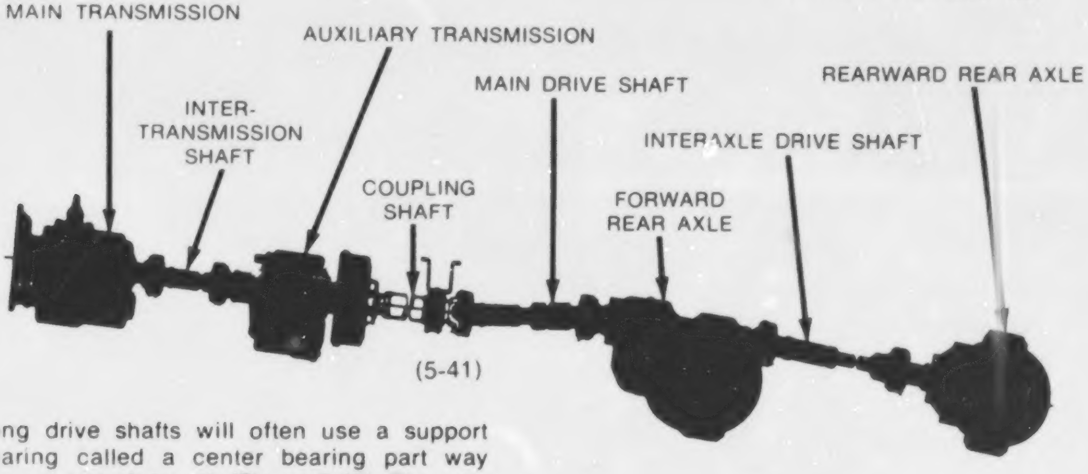

YOKE
LOCK PLATE
BEARING CAP
SPIDER
CAPSCREWS
BEARING CAP
LOCK PLATE

(5-40) BOLTED END CAP TYPE U-JOINT

Courtesy of Ford Motor Co

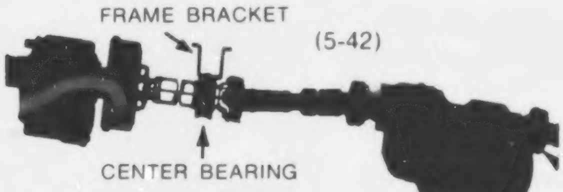
In a power train the transmission is mounted rigidly, but the axle housings are moveable. Thus, splined slip joints are needed to allow for change in shaft length as the housings move up and down. In the drive line of the tandem axle truck, shown in Figure 5-41 the inter transmission shaft, main drive shaft and interaxle drive shaft all have splined slip joints to allow for length change of the shafts as the components move in relation to one another.

Courtesy of Ford Motor Co



(5-41)

Long drive shafts will often use a support bearing called a center bearing part way down the shaft length (Figure 5-42). The center bearing will be pressed on the drive shaft. A rubber casing is installed over the bearing, and the whole assembly is supported by a bracket attached to the frame.



(5-42)

Courtesy of Ford Motor Co

DRIVE AXLES

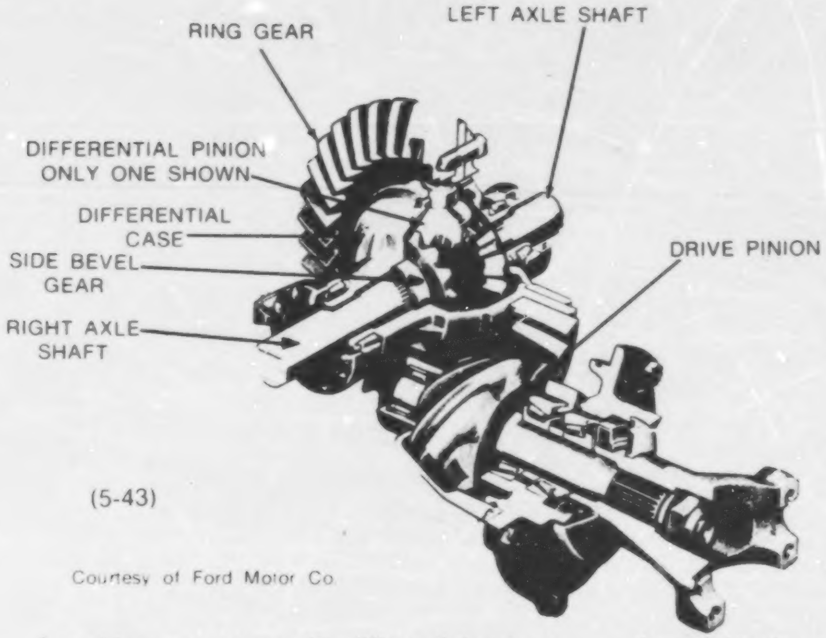
The drive axle, often called the differential, does three jobs:

1. Provides a gear reduction.
2. Changes the direction of the power flow.
3. Allows the outside wheel to turn faster than the inside wheel when the vehicle turns a corner.

As was seen earlier, a basic drive axle consists of a pinion and a ring gear. Power from the engine is transmitted via the drive shaft to the pinion which drives the ring gear. At this point in the power train two things are happening:

1. A gear reduction occurs as a smaller gear is driving a larger gear.
2. The flow of power is turned 90° out to the wheels.

If the machine went straight and never turned, the ring and pinion would be all the gears required at the rear axle. But vehicles do turn so the outside wheel must travel farther than the inside and thus must travel faster. To allow the wheels to travel at different speeds when turning a differential is required. The differential has four bevel pinion gears and two side bevel gears (Figure 5-43). The bevel pinions and side gears are enclosed in a case that is bolted to the ring gear. The two side bevel gears are splined to the axle shafts that go to each wheel. Since it is very difficult to understand in words how the differential gears work, study the gear movement of an actual differential.



(5-43)

Courtesy of Ford Motor Co.

A problem can occur with differentials when one wheel looses traction and starts spinning. Various devices have been made to prevent this spinning and a differential equipped with one is called a locking differential. These locking devices may be mechanical, hydraulic, or automatic; the automatic is most common today. Essentially, the locking device locks out differential action in poor traction conditions but allows normal action under good ground conditions.

TYPES OF DRIVE AXLES

There are many variations in drive axle designs. Some variations are:

single reduction
double reduction
single speed
two speed
front mount
top mount
standard differential
locking differential

Axle shafts are divided into two general groups:

— dead axles
— live axles

A dead axle doesn't move: it is stationary while a wheel turns on it. Examples of dead axles are a trailer axle and a front wheel spindle.

A live axle moves; it is attached to a wheel and the wheel and axle turn together. The axle shaft transferring power from the differential to the wheels is a live axle. Live axles are also referred to as floating axles.

Dead axles can be made of either tubular or solid steel. Live axles are constructed of solid steel capable of withstanding the twisting stress of the torque that the axle transmits. One end of a live axle is splined to fit into the differential gears. The other end can be connected to the wheel in various ways such as a bolted flange, a splined end that fits into a flange cap, or a splined end that fits into the sun gear of a planetary gear set.

Live Axles

Two kinds of live axles are used in automobiles and trucks today:

Full-Floating Axles,

turns wheels, but doesn't carry the weight of the vehicle.

Semi Floating Axles,

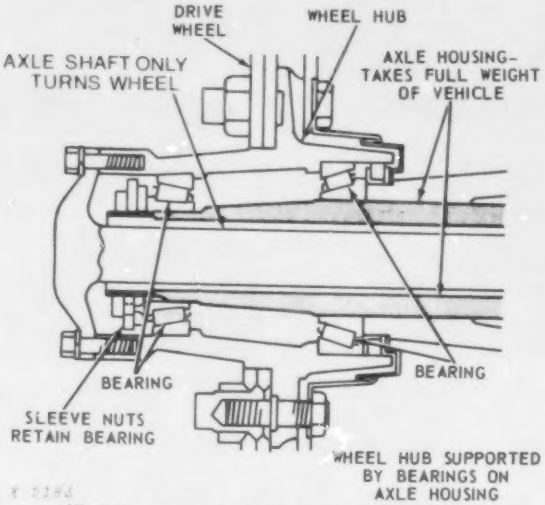
turns wheels as well as carrying the weight of the vehicle.

Full-Floating Axles

Full-floating axles (Figure 5-44) are used in many heavy duty trucks. Each drive wheel and hub turns on the outer end of the axle housing on a pair of tapered roller bearings. The bearings are positioned outside the axle housing. In this way the axle housing takes the full weight of the vehicle and absorbs all stress or end thrust caused by turning, skidding, etc. The axle shaft only transmits the torque from the engine and is said to float in the axle housing. The most common full-floating axle is splined at the differential and has a flange at the other end. The flange is bolted to the outside of the wheel hub. On machines with planetary final drives the axle will be splined at both ends.

Full-Floating Axle

Courtesy of John Deere Ltd.


DRIVE WHEEL
WHEEL HUB
AXLE SHAFT ONLY TURNS WHEEL
AXLE HOUSING-TAKES FULL WEIGHT OF VEHICLE
BEARING
BEARING
SLEEVE NUTS RETAIN BEARING
WHEEL HUB SUPPORTED BY BEARINGS ON AXLE HOUSING
X 2183

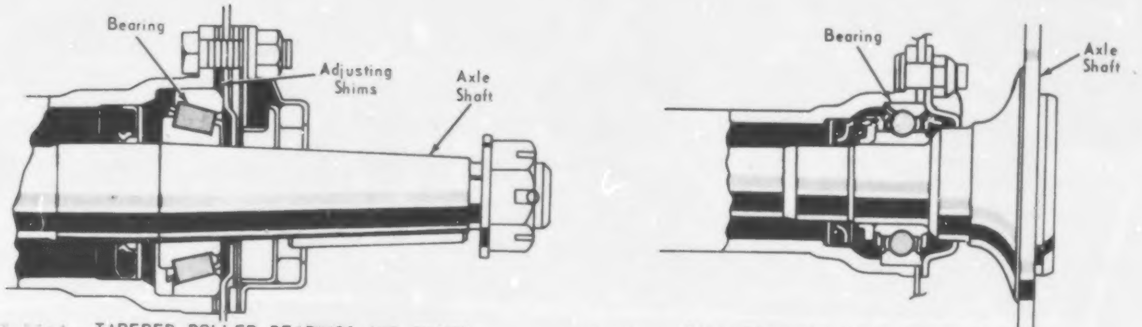
(5-44) FULL-FLOATING AXLE SHAFT

Semi-Foating Axles

Semi-floating axles (Figure 5-45) fit into the differential and turn within the axle housing the same way as full-floating axles. However, there is a critical difference in the two axles. With a full-floating axle, the wheel and hub turn on the axle housing and the axle shaft just transmits drive torque. On the other hand, with a semi-floating axle the wheel and hub are attached to the outer end of the axle. Therefore, the axle shaft supports the vehicle's weight as well as transmitting drive torque. It must take all the weight and all the stresses caused by road impact, turning, and skidding.

The outer end of a semi-floating axle is supported by one bearing that is pressed onto the axle shaft and fits into the axle housing. Two types of bearings are used: tapered roller bearings or ball bearings. Where tapered roller bearings are used, an adjustment for axle shaft end play is provided. The adjustment is made with shims or a nut located at one end of the axle housing. In order to transmit equally shaft end thrust to the bearings at both ends of the axle housing, a thrust bloc — or spacer — is located between the inner ends of the two axle shafts within the differential carrier.

Semi-floating axles are commonly used in automobiles and light trucks. The outer ends of the shaft may be flanged or tapered as shown below. When the shaft is tapered, the wheel hub is keyed to the shaft and locked in place with a nut.


Bearing
Adjusting Shims
Axle Shaft
Bearing
Axle Shaft

X 2184 TAPERED ROLLER BEARINGS AND SHAFT

X 2185 BALL BEARINGS AND FLANGED SHAFT

Courtesy of John Deere Ltd

(5-45) SEMI-FLOATING AXLE SHAFTS
TWO TYPES

RETARDERS

A retarder (Figure 5-46) supplements the main braking system of a vehicle. A retarder cannot stop a vehicle by itself. Rather, it assists the brakes in stopping the vehicle. From outward appearance, a retarder looks similar to a torque converter. In actual fact though, the retarder performs an opposite function to a converter, absorbing torque rather than transmitting it.

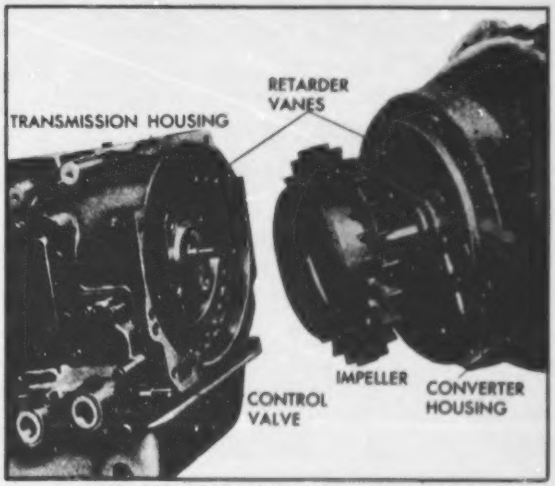
Hydraulic retarders are mounted in the power train at one of three locations:

1. In the engine behind the flywheel.
2. In the transmission between the converter and the transmission.
3. Within the drive line.

A retarder consists of three basic parts: a housing, rotor, and stator (Figure 5-47).

In addition, the retarder requires some means of applying oil under pressure (a load cylinder) and a means of cooling the oil (an oil cooler).

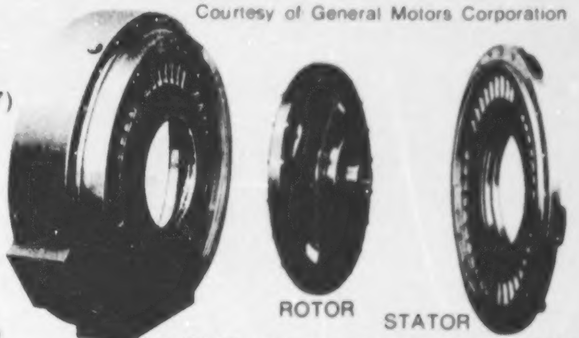
Figure 5-48, is a diagram of an engine retarder system:


TRANSMISSION HOUSING
RETARDER VANES
CONTROL VALVE
IMPELLER
CONVERTER HOUSING

(5-46) TRANSMISSION RETARDER

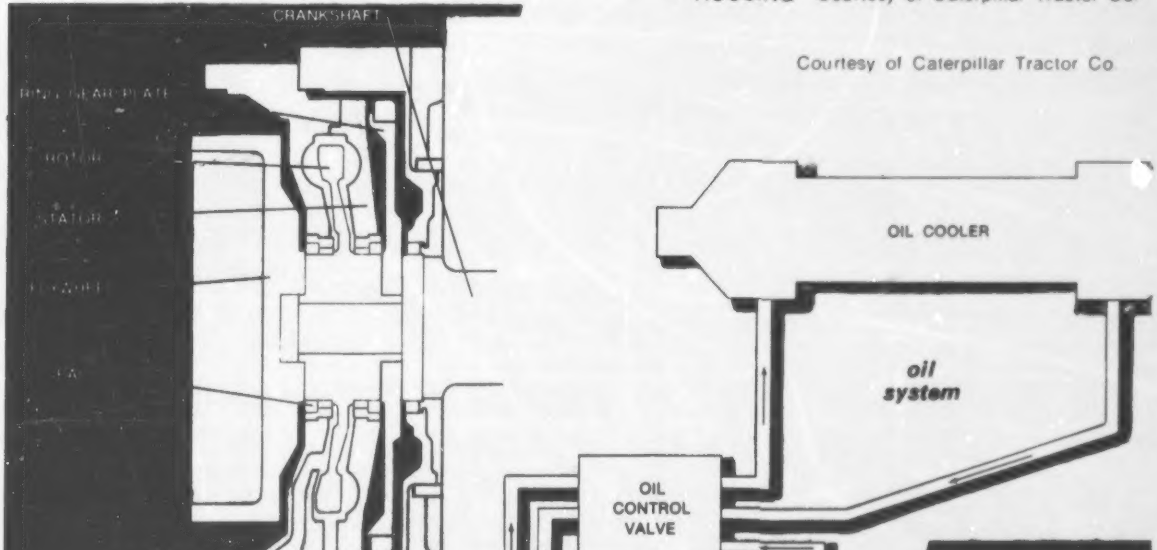
Courtesy of General Motors Corporation

(5-47)


HOUSING
ROTOR
STATOR

Courtesy of Caterpillar Tractor Co.

(5-48) SCHEMATIC OF ENGINE RETARDER


CRANKSHAFT
RING GEAR PLATE
ROTOR
STATOR
FLYWHEEL
OIL COOLER
oil system
OIL CONTROL VALVE
CHARGING PUMP

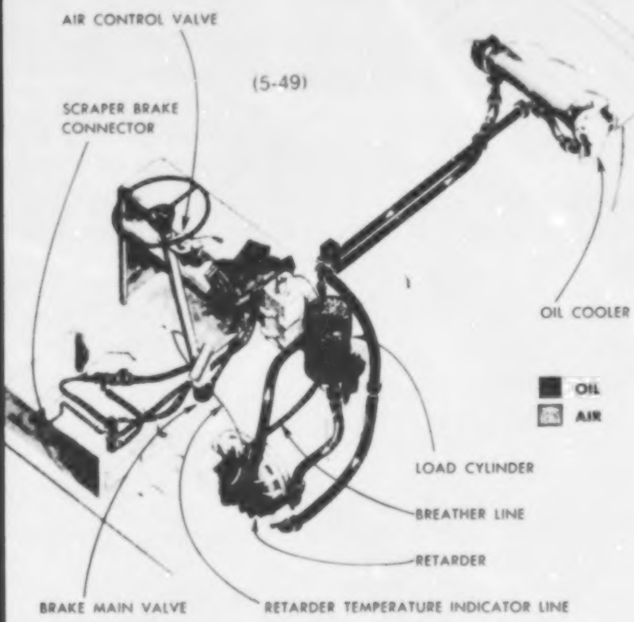
Courtesy of Caterpillar Tractor Co.

In a retarder the housing is the stationary component and the rotor is the moving one. The rotor is driven by the engine, transmission or drive line. The internal surface of the housing has fins on one or both sides of the rotor. The rotor may also have fins on one or both sides, depending on how the housing is made. The rotor runs with a very close tolerance to the housing.

When the retarder is in the unapplied position, oil freely circulates within the retarder housing, causing little or no drag on the rotor (i.e., the drive train). When the retarder is activated by applying air pressure to the oil, the pressurized oil is churned and sheared between the closely tolerated housing and rotor, causing a strong resistance which slows the rotor and thus the drive train. By resisting drive train motion, the retarder helps slow down the vehicle.

Friction in the retarder creates heat that must be dissipated. This is done by circulating through a cooler and back into the retarder (Figure 5-49).

The source of a retarder's oil depends on its location. An engine retarder uses engine oil and a transmission retarder uses transmission oil. A drive line retarder, not having an immediate source of oil, has its own oil supply.



(5-49)

Courtesy of Caterpillar Tractor Co

The degree of retarding effect produced by a retarder is controlled by the operator through a foot or a hand controlled valve. When using the retarder, the operator should keep in mind that the retarder is only meant to assist the brakes not to replace them, and that the engine RPM's should be kept up to provide sufficient air flow for the retarder cooler.

GREASE AND OIL

Before getting into preventive maintenance on power trains a discussion on grease and oil is necessary.

Grease

Grease consists of an oil of a certain viscosity range (viscosity is the resistance of a liquid to flow) combined with a thickening agent such as soap. Additives are included to give stronger wear and performance qualities to the grease:

GREASE = OIL + SOAP + ADDITIVES

The following additives go into grease (and into oil):

oxidation, corrosion and rust inhibitors, extreme pressure and anti-score agents

Types of Grease

Some common types of grease are:

1. lithium soap grease — multi-purpose
2. calcium or lime soap grease — cup grease
3. aluminum soap grease — excellent chassis grease
4. sodium or soda soap grease — wheel bearings
5. barium soap grease — not common — special application

Each grease has qualitites that allow it to do a certain job. Note that some greases are incompatible and should never be mixed together. All manufacturers specify what grease must be used on different parts of their equipment. Whenever a part is to be greased, always refer to the service manual for the correct type of grease to be used. Here is an example from a service manual for a tractor-scraper stating what kind of grease to use:

LUBRICATING GREASE

Use Multipurpose-type Grease (MPGM) which contains 3 - 5% molybdenum disulfide conforming to MIL-M-7866, and a suitable corrosion inhibitor. NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or No. 0 Grade for extremely low temperatures.

Gear Oils

Oils have the same additives as grease (oxidation, corrosion, rust inhibitors; extreme pressure and anti-score agents) but also include the following: friction modifiers, pour point depressants, foam depressants.

Oils are classified according to their viscosity and their performance characteristics. The Society of Automotive Engineers (S.A.E.) classifies oils by viscosity using numbers like:

75W
80W — the higher the number the greater the oil's viscosity (the thicker the oil)
85W
90W
140W

The American Petroleum Institute (API) classifies oil by performance, by the type of work the oil is suited for. API uses a numbering system for gear oils as follows:

GL 1	straight mineral oil
GL 2	straight mineral oil with anti-wear additives
GL 3	mild extreme pressure additives
GL 4	All have extreme pressure additives to handle increased loading, but each has different specifications to meet manufacturer's requirements.
GL 5	
GL 6	

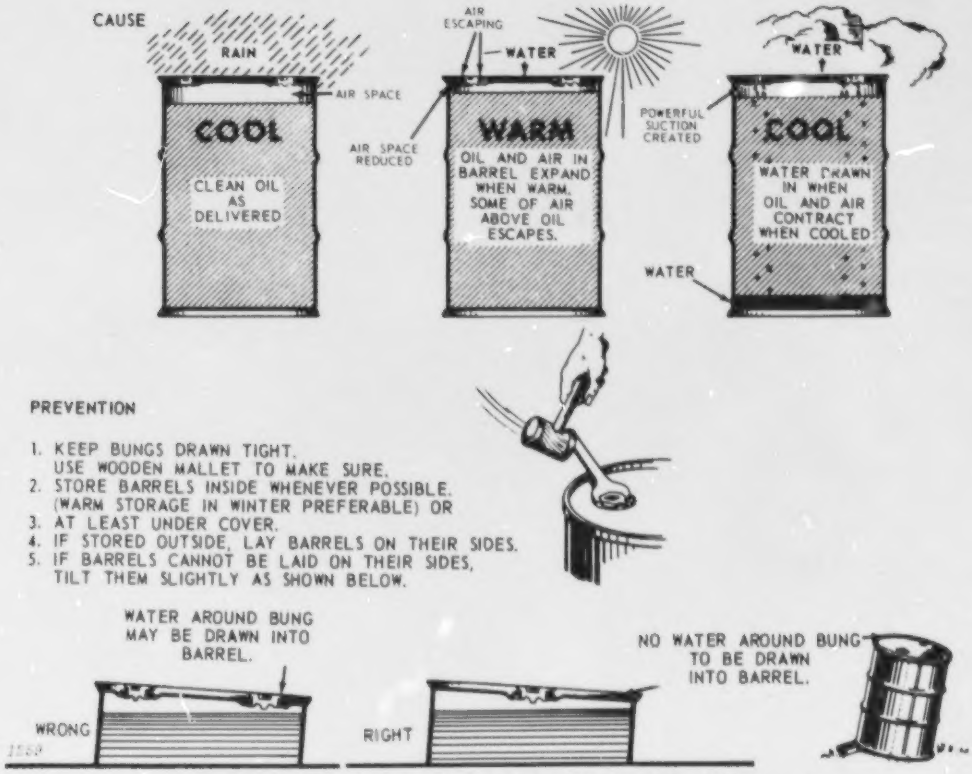
As with grease, manufacturers specify the type of oil that must be used in a given part or system. When topping up or changing oil always check the service manual for the correct type and amount of oil to use. For example, the manufacturer will recommend that you use an oil equivalent to GL-5-SAE 90. Each oil company will have a product name for its oil, but it will also give the GL and SAE rating.

CARE OF LUBRICANTS

Lubricating oils and greases are highly refined products, made to meet rigid specifications. Lubricants must be correctly stored, handled and dispensed if they are to do the job they are designed for. Clean, uncontaminated lubricant is essential to properly service or assemble mechanical equipment.

GOOD PRACTICES IN HANDLING, DISPENSING AND STORING LUBRICANTS

1. Always use clean containers for dispensing lubricants.
2. Rinse and cover containers when not in use to prevent dirt and moisture contamination, e.g., wheel bearing grease containers.
3. When adding oil or changing filters clean the oil cap or cover before removing it.
4. Always clean grease fittings before applying the grease gun.
5. Keep lids on barrels and buckets when not in use.
6. Whenever possible store lubricants in a clean, closed room or area and at a fairly even temperature. Over long periods of time extreme temperature changes can alter the lubricants' characteristics.
7. If lubricants are stored outside, lay the barrels on their side or tilt them slightly, positioning the bungs at the sides. Be sure the bungs are kept tight. This practice will prevent water from entering the lubricant through expansion and contraction of the barrels. If the barrels are not under cover, cover them with a tarpaulin when they are not in use. Always clean the top of a barrel before opening it.


CAUSE
RAIN
AIR SPACE
COOL
CLEAN OIL AS DELIVERED
AIR ESCAPING
WATER
AIR SPACE REDUCED
WARM
OIL AND AIR IN BARREL EXPAND WHEN WARM. SOME OF AIR ABOVE OIL ESCAPES.
WATER
POWERFUL SUCTION CREATED
COOL
WATER DRAWN IN WHEN OIL AND AIR CONTRACT WHEN COOLED
WATER
WATER AROUND BUNG MAY BE DRAWN INTO BARREL.
WRONG
RIGHT
NO WATER AROUND BUNG TO BE DRAWN INTO BARREL.

PREVENTION

1. KEEP BUNGS DRAWN TIGHT. USE WOODEN MALLET TO MAKE SURE.
2. STORE BARRELS INSIDE WHENEVER POSSIBLE. (WARM STORAGE IN WINTER PREFERABLE) OR
3. AT LEAST UNDER COVER.
4. IF STORED OUTSIDE, LAY BARRELS ON THEIR SIDES.
5. IF BARRELS CANNOT BE LAID ON THEIR SIDES, TILT THEM SLIGHTLY AS SHOWN BELOW.

(5-50) STORAGE PRACTICES WHICH PREVENT CONTAMINATION OF OIL

Courtesy of John Deere Ltd

QUESTIONS — POWER TRAINS

1. Match each component below with the job it performs listed at the right.

   (a) clutch 1. equalizes power for turning
   (b) transmission 2. connects and disconnects power
   (c) differential 3. selects speeds and direction

2. List the three basic methods of transmitting power and give an example of each.

3. When a small gear drives a large gear there is a speed decrease and a torque increase. True or False?

4. Calculate the gear ratio when a 13 tooth gear drives a 52 tooth gear. If the small gear travels at 6000 RPM's, what is the speed of the larger gear?

5. What is the advantage of a helical gear over a straight spur gear?

6. A planetary gear set consists of a:

   (a) ring gear, one planet pinion and a sun gear
   (b) ring gear, a drive and a sun gear
   (c) ring gear, carrier, and internal gear
   (d) ring gear, carrier and sun gear

7. In a planetary gear set where the ring gear is held and the sun gear is powered, there is a:

   (a) speed increase to the carrier in the same direction
   (b) speed decrease to the carrier in the same direction
   (c) speed decrease to the carrier in the opposite direction
   (d) speed decrease and torque increase to the carrier in the same direction
   (e) both (b) and (d) are right

8. When two gears are in mesh, what does the term backlash refer to?

9. In an engine clutch, what is the advantage of adding a second friction disc and an intermediate pressure plate?

10. Why is the friction lining on clutch packs usually different than the friction lining on an engine clutch?

11. Give two advantages of a jaw clutch.

12. A torque converter can multiply the torque it receives from the engine. True or False?

13. A torque converter consists of three main parts: a pump, a turbine and a ______.

14. Briefly explain the advantage of a multi-countershaft transmission over that of a single countershaft.

15. What are the two basic types of power shift transmissions?

16. Shifts for speed and direction in a power shaft transmission are made:

   (a) automatically
   (c) manually
   (c) semi-manually
   (d) semi-automatically

17. What is the reason for having an auxiliary transmission?

18. What is the purpose of the splined slip joint on a drive shaft?

19. What three jobs does the drive axle do?

20. The function of a locking differential is to:

   (a) speed the wheels up in poor traction conditions
   (b) stop one wheel and allow the other to drive in poor traction conditions
   (c) stop both wheels in poor traction conditions
   (d) lock out differential action in poor traction conditions

21. Two general classifications of axle shafts are:

   (a) long and short
   (b) dead and live
   (c) small and large
   (d) left and right

22. What is the difference between a live axle and a dead axle?

23. How does a retarder differ from a torque converter? Can a retarder be used to stop a vehicle?

PREVENTIVE MAINTENANCE SERVICE OF POWER TRAINS

Preventive maintenance service of Power Trains on a daily basis should consist of a thorough visual check of all the drive components from the engine out. Look for:

1. Loose parts — Power train components involve many moving parts that carry heavy torques and stresses. These parts can work loose. Check especially the areas where power is transmitted from a stationary part to a moving one, i.e., transmission and drive shaft.
2. Oil leaks — There are a number of oil compartments, and in some cases connecting hoses, in power trains. Under stress and heat, leaks will develop. Make any minor repairs, and report major ones. Oil level checks will be made on a scheduled basis.
3. Faulty adjustment — To compensate for running wear, adjustments need to be made on belts, chains, clutches. Adjusting clutches will probably be the most common adjustment a first year apprentice will do, and is detailed below.

CLUTCH ADJUSTMENT

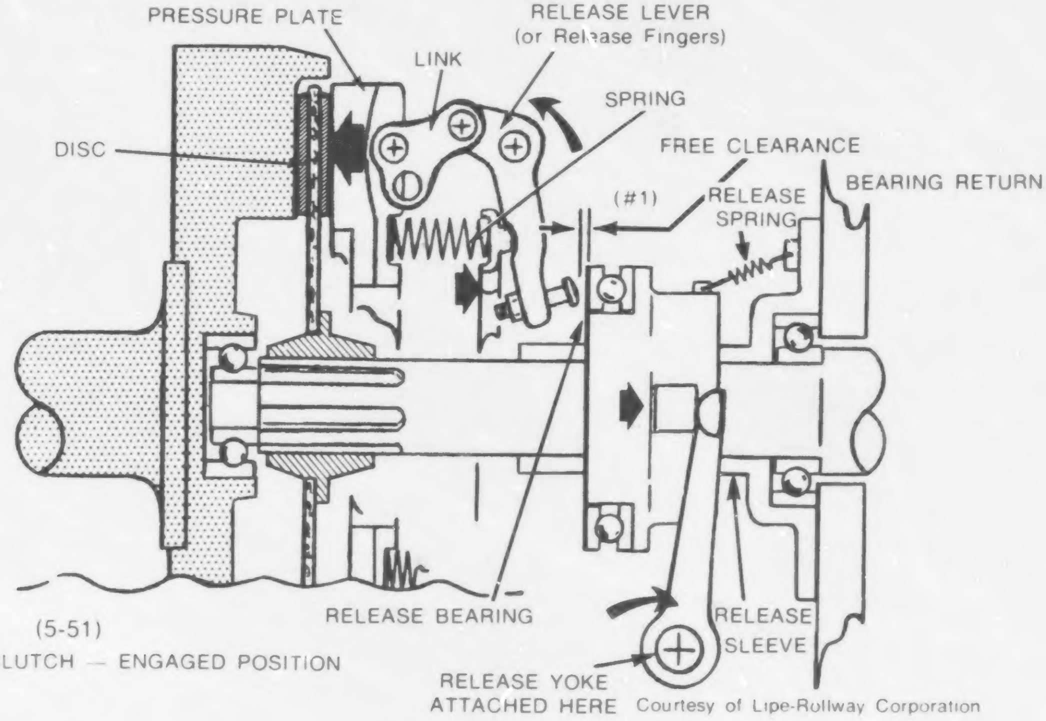
A major factor in clutch adjustment is working conditions. Under ordinary conditions clutches can go thousands of miles and not need adjustment. Under very stressful conditions the clutch may need adjusting daily. Another factor affecting clutch adjustments is the operator. Some drivers or operators are hard on clutches and their clutches will need more frequent adjustment.

Clutch adjustment varies with the type of clutch. A push clutch (i.e., the release bearing is pushed to disengage) is used on smaller vehicles. This type of clutch has an adjusting mechanism such as a threaded rod located externally on the linkage. Larger vehicles generally use a pull clutch (the release bearing is pulled to disengage) which is adjusted internally or inside at the pressure plate. Clutch brakes are used in conjunction with pull clutches. A clutch brake slows down the transmission input shaft on unsynchronized transmissions to aid in shifting.

Clutch brakes are applied with the clutch pedal when the pedal is approximately one inch from the floor boards. Adjustment to clutch brakes are made externally on the linkage.

Clutch Clearance

Clutch clearance is the amount of clearance between the release bearing and the release levers, point #1 in Figure 5-51 showing a simplified view of a push clutch.



(5-51)
PUSH CLUTCH — ENGAGED POSITION

Courtesy of Lipe-Rollway Corporation

The correct clearance prevents the release bearing from riding constantly against the release fingers of the pressure plate. As wear occurs on the disc facings, the release levers move towards the release bearing taking up the clearance. If the movement of the release levers is not compensated for, the pressure against the release bearings will cause the clutch to slip under load.

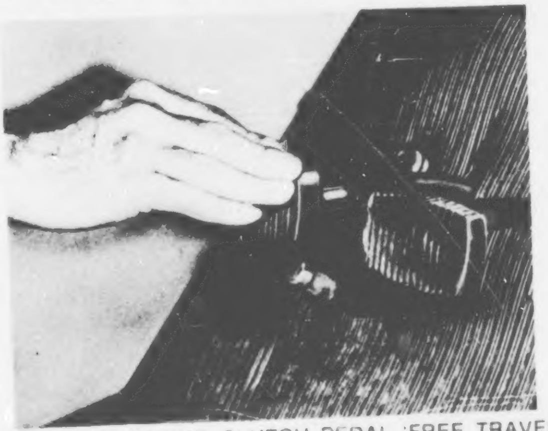
The clutch adjustment for this push clutch would be a threaded rod located outside the clutch housing. Adjusting the threaded rod would pull the release bearing back on the release sleeve making a gap (#1) between the bearing and the release levers of the pressure plate. This gap has to be wide enough to let the release bearing be free of the release levers when the clutch is fully engaged, but narrow enough to allow the release bearing to fully disengage the pressure plate when the clutch pedal is completely depressed.

Correct clearance between the release bearing and release levers will usually give approximately 1 1/2" of free travel at the pedal. Therefore, a check of clutch pedal free travel will tell if the clutch needs adjustment.

Below is a typical section from a service manual on clutch adjustment. The clutch referred to is a basic push clutch.

Clutch Pedal Adjustment

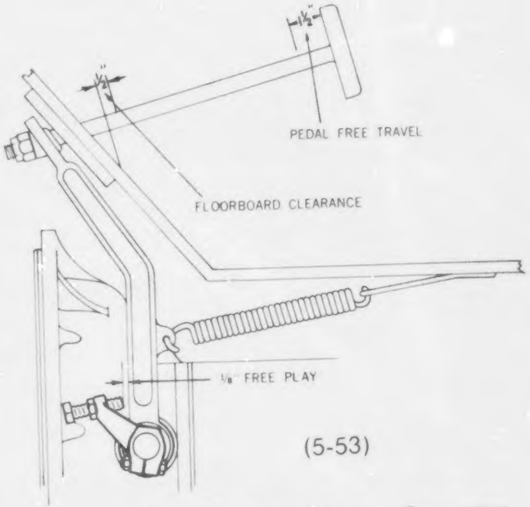
1. The clutch must be kept in proper adjustment by frequent inspection of clutch free travel, the first easy movement of the clutch pedal.
2. Check the clutch pedal free travel by hand (Figure 5-52) and be sure that the free travel is a result of actual release bearing clearance and is not caused by worn linkage or faulty hydraulic cylinders.



(5-52) CHECKING CLUTCH PEDAL 'FREE TRAVEL'

Courtesy of Lipe-Rollway Corporation

3. The proper clutch pedal free travel is approximately 1 1/2". The gradual reduction from this amount is a normal condition caused by facing wear.
4. If inspection indicates clutch pedal free travel is less than 1/2", immediate adjustment should be made to restore the proper 1 1/2" travel. This 1 1/2" of free travel normally results in 1/8" clearance between the release bearing and the release levers. Figure 5-53 shows a correctly adjusted push clutch.



(5-53)

Courtesy of Lipe-Rollway Corporation

Below is a typical adjustment procedure for a pull clutch equipped with a clutch brake. Adjustment to the clutch is made internally; the release bearing assembly is reached by removing a cover on the underside of the flywheel. Note: The clutch brake may also have to be adjusted (it is adjusted externally), depending on what has previously been done to it.

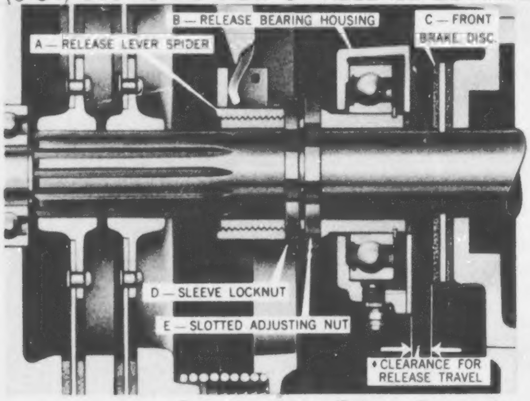
Clutch Adjustment

1. Unlock sleeve locknut "D" (Figure 5-54).
2. Turn slotted spanner adjusting nut "E" for proper clearance.

   7/16" for 14"-2PT
   1/2" for 15 1/2"-2PT

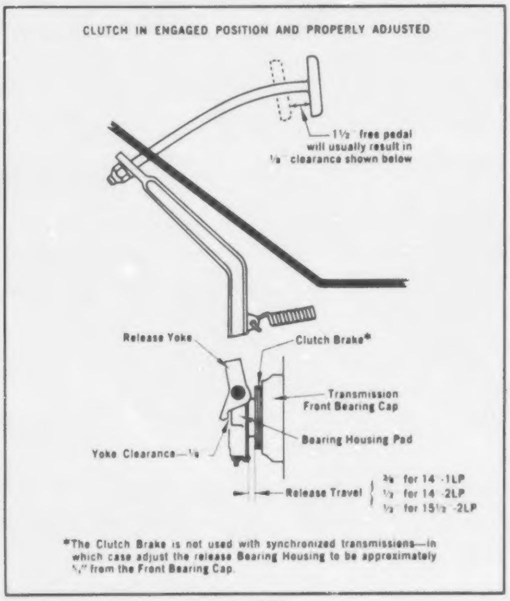
3. Lock sleeve locknut "D".

(5-54) SECTIONAL VIEW OF RELEASE BEARING


A — RELEASE LEVER SPIDER
B — RELEASE BEARING HOUSING
C — FRONT BRAKE DISC
D — SLEEVE LOCKNUT
E — SLOTTED ADJUSTING NUT
♦ CLEARANCE FOR RELEASE TRAVEL

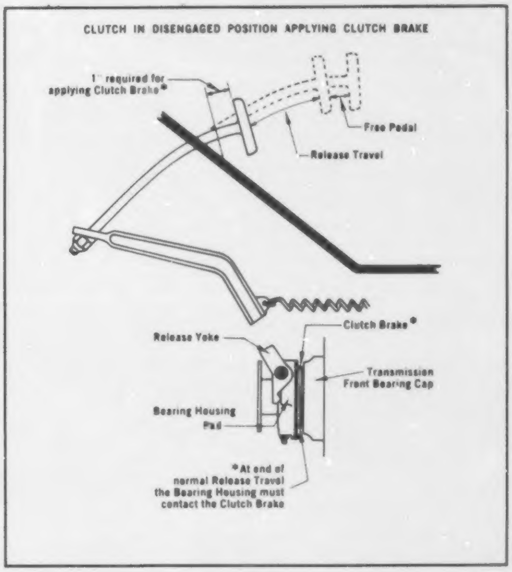
Courtesy of Lipe-Rollway Corporation

Figure 5-55 shows a properly adjusted pull clutch in engaged and disengaged positions.


CLUTCH IN ENGAGED POSITION AND PROPERLY ADJUSTED
1½" free pedal will usually result in ⅛" clearance shown below
Release Yoke
Clutch Brake*
Transmission Front Bearing Cap
Bearing Housing Pad
Yoke Clearance—⅛"
Release Travel
⅜" for 14" -1LP
½" for 14" -2LP
½" for 15½" -2LP
*The Clutch Brake is not used with synchronized transmissions—in which case adjust the release Bearing Housing to be approximately 1/16" from the Front Bearing Cap.

(5-55)

Courtesy of Lipe-Rollway Corporation


CLUTCH IN DISENGAGED POSITION APPLYING CLUTCH BRAKE
1" required for applying Clutch Brake*
Free Pedal
Release Travel
Release Yoke
Clutch Brake*
Transmission Front Bearing Cap
Bearing Housing Pad
*At end of normal Release Travel the Bearing Housing must contact the Clutch Brake

(5-55)

Courtesy of Lipe-Rollway Corporation

Lubricating Release Bearings

Lubrication of the release bearing is very important on large equipment. (Release bearings for clutches in smaller vehicles are prepacked). An example of lubrication instructions are shown below:

1. The release bearing housing has not been pre-packed with grease! It must be lubricated when the clutch is installed in the vehicle or premature failure will occur.
2. Only high temperature greases should be used. Chassis lube or all purpose lubricants are not recommended.
3. Add lubricant at each chassis lubrication period or more often if service is extreme. Only a small amount is required.
4. To assure adequate distribution of the grease throughout the bearing, the engine should be running while grease is being added.

SCHEDULED MAINTENANCE ON POWER TRAINS

Scheduled maintenance on power trains specifically refers to checking the oil levels and changing the oil. At the same time that scheduled maintenance is carried out, though, check for loose parts, oil leaks, and make necessary running adjustments.

Note that the manufacturer's time schedule for checking and changing oil generally applies when the machine is working under normal conditions. If a machine is working under severe conditions, the oil should be checked and changed more frequently than stated in the service manual.

The procedures to change the oil on a manual transmission, power shift transmission, drive axle or final drive are much the same, although the locations of the drain, the fill plug and level plug, filters and screens differ from machine to machine. See service manuals for specific instructions.

Some general points when changing oil are:

1. Before removing a drain plug be sure you know the capacity of the housing and have a drain bucket large enough to hold all the oil.
2. Have the component up to operating temperature before draining.
3. When removing the drain plug be careful of the hot oil.
4. If the component is equipped with a filter(s) remove it and clean the housings. Install a new filter. Take a minute to cut the old filter apart and see if it has trapped any metal chips.
5. Clean all accumulated material from magnetic drain plugs.
6. If the component is equipped with a sump and screen, remove and clean them.
7. Some manufacturers recommend flushing housings with flushing oil or with kerosene. Flush only if recommended.
8. Be sure to refill the housing with the correct (1) type and (2) amount of oil. Do not overfill.
9. On power shift machines run the engine to charge the converter. Check the filters for leaks and recheck the oil level. Note that some transmissions require that the engine be running when making the final oil level check.

LUBRICATION SERVICE EXAMPLES

Following are examples of power train lubrication service taken from Service Manuals for three different machines:

1. Manual transmission for an on or off-highway truck.
2. Crawler Tractor with a power shift transmission.
3. Wheel loader with a power shift transmission and standard drive axles.

Note the different style in which each of these manufacturers present their lubrication information.

LUBRICATION FOR ON AND OFF—HIGHWAY MANUAL TRANSMISSIONS
(Courtesy of Eaton Corporation)

LUBRICATION

RECOMMENDED LUBRICANTS

Heavy-duty engine oil. Make sure to specify heavy-duty type meeting MIL-L-2104B specifications.

Mineral gear oil inhibited against rust, oxidation and foaming.

Extreme pressure oils under some conditions might form carbon deposits on gears, shafts, bearings and synchronizer discs, and may also glaze friction surfaces of synchronizer discs — conditions which will result in transmission malfunction and premature failure. It is suggested that if these conditions exist, and E.P. oil is being used, a change should be made to mineral oil or heavy-duty engine oil as recommended.

ON-HIGHWAY VEHICLES

Type	Grade	Temperature
Heavy Duty Engine Oil MIL-L-2104B	SAE 50 SAE 30	Above + 10°F. Below + 10°F.
Mineral Gear Oil R and O Type	SAE 90 SAE 80	Above + 10°F. Below + 10°F.
Mild E.P. Oil, except Sulfur-chlorine-lead type MIL-L-2105B	SAE 90 SAE 80	Above + 10°F. Below + 10°F.
OFF-HIGHWAY AND MINING EQUIPMENT		
Heavy Duty Engine Oil MIL-L-2104B	SAE 50 SAE 30	Above + 10°F. Below + 10°F.
Special Recommendation — For extreme cold weather where temperature is consistently below 0°F.		
Heavy Duty Engine Oil MIL-L-2104B	SAE 20W	Below 0°F.

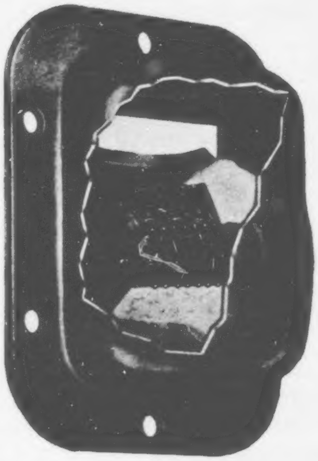
(5-56) Courtesy of Eaton Corporation

These TRANSMISSIONS are designed so that the internal parts operate in a bath of oil circulated by the motion of gears and shafts. Grey iron parts have built-in channels where needed, to help lubricate bearings and shafts.

Thus, all parts will be amply lubricated if these procedures are closely followed:

1. Maintain oil level. Inspect regularly.
2. Change oil regularly.
3. Use the correct grade and type of oil.
4. Buy from a reputable dealer.

To keep the gear oil clean between oil changes use the Fuller Transmission Gear Oil Filter which can be attached to the right-side power take-off opening. This assembly includes a replaceable filter element that removes the accumulation of metallic particles, road dirt and grit deposited in the lubricant.



(5-57) TRANSMISSION GEAR OIL FILTER

Courtesy of Eaton Corporation

Draining Oil

To drain the transmission remove the drain plug at bottom of case. Drain oil when transmission is warm. After the transmission has been drained, and before it is refilled, the case should be thoroughly flushed with a clean flushing oil or kerosene. Do not use flushing compound if unit is equipped with side or front mounted pressure lubrication pumps unless pump is removed and opening covered with plate. Clean the drain plug before reinstalling.

Refilling

Before removing the filler plug on left side of case, all dirt should be removed from the area of the case adjacent to the filler opening. Fill the transmission to the level of the filler opening, metering approximately 25 pints to 28 pints of gear oil into the transmission. The exact amount will depend upon the inclination of the transmission and model designation. In every instance, fill to the level of the filler opening.

Do not overfill. Overfilling will cause oil to be forced out of the case through the mainshaft openings.

Adding Oil

It is recommended that types and brands of oil not be intermixed because of possible incompatibility.

Operating Temperature

It is imperative that the operating temperature of the transmission does not exceed 250°F.

Extensive operation at temperatures exceeding 250°F will result in rapid breakdown of the oil and shorten transmission life.

Transmissions used in stationary equipment, or in vehicles operating at slow road speeds, may have to be equipped with external coolers so that the 250°F temperature is not exceeded.

Inspection

Gear oil is to be kept even with the level of the filler opening at all times. Check at the following intervals:

Highway Service	1,000 miles
Off-highway Service	40 hours

Gear Oil Change

Change the gear oil on all new equipment after the first 3000 to 5000 miles (on-highway), or first 40 hours (off-highway); thereafter, make oil changes as follows:

Highway Service	25,000 miles
Off-highway Service	
Logging and associated operations	1,000 miles
Dirt moving, mining and associated operations	250 to 500 hours, as indicated by operation and contamination of lubricant.

Special Recommendation

The above oil inspection and change periods are based on the average use and operating conditions for the applications listed. It is recommended that the individual owner make a periodic lab analysis of the lubricant to determine contamination based on the individual's own operating conditions. After this has been determined, the individual owner can then set his own inspection and oil change periods.

Clutch Release Bearing

Follow vehicle manufacturer's chassis lubrication recommendations.

Oil Filter

If so equipped, replace filter element at each oil change; clean filter element housing.

Courtesy of Eaton Corporation

LUBRICATION AND MAINTENANCE CHECKS FOR A CRAWLER DOZER (CAT D6) WITH A POWER SHIFT TRANSMISSION

(Courtesy of Caterpillar Tractor Co.)

Lubricating Grease

Use Multipurpose-type Grease, NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 0 or No. 1 Grade for extremely low temperatures. Wipe all fittings, caps and plugs before servicing.

Lubricating Oils

Superior Lubricants (Series 3): API Engine Service Classification CD: Additive type oils that meet rigid, high quality standards and are certified for use in Caterpillar diesel engines. Must contain zinc dithiophosphate when used in a hydraulic system.

NIL-L-2104A Oil, API Engine Service Classification CA; or MIL-L-2104B Oil, API Engine Service Classification CC: Additive type oils, but milder than Superior Lubricants (Series 3).

Multipurpose-type Gear Lubricant (MIL-L-2105B); API Gear Lubricant Designation, GL-5: Used in gear compartments where gear loads and speeds are factors. In extremely cold temperatures consult your oil supplier for special Arctic Lubricants.

Your oil supplier is familiar with the oils meeting those requirements.

RECOMMENDED LUBRICANT AT VARIOUS STARTING TEMPERATURES				
COMPARTMENT OR SYSTEM	**ABOVE 32°F (0°C)**	**32°F to 10°F (0°C to -12°C)**	**(-12°C to -23°C) 10°F to -10°F**	**BELOW -10°F (-23°C)**
SUPERIOR LUBRICANTS (SERIES 3) ONLY				
Diesel engine crankcase	SAE 30	SAE 10W(1)	SAE 10W(1)	SAE 10W(1)
Transmission, bevel gear and steering clutches	SAE 30	SAE 30	SAE 10W	SAE 10W
Cable control gear case	SAE 30	SAE 30	SAE 10W	SAE 10W
SUPERIOR LUBRICANTS (SERIES 3), MIL-L-2104B				
Hydraulic system	SAE 10W	SAE 10W	SAE 10W(2)	SAE 10W(2)
MULTIPURPOSE-TYPE GEAR LUBRICANT MIL-L-2105B				
Final drives	SAE 140(3)	SAE 90	SAE 90	SEE NOTE(4)

(1) SAE 10W oil may be used in the diesel engine even if daytime ambient temperature rises to 70°F (21°C). Below -10°F (-23°C) it may be necessary to warm the engine oil so the engine can be cranked and the oil will circulate freely.

(2) Certain Industrial-type Hydraulic Oils may be used at extremely low temperatures. Consult your oil supplier for oil meeting this requirement.

(3) SAE 140 must not be used when the ambient temperature is below 32°F (0°C).

(4) Consult your oil supplier for special Arctic Lubricants.

(5-58) Courtesy of Caterpillar Tractor Co

ITEM	SERVICE	Lubricant	Maintenance
EVERY 10 SERVICE HOURS OR DAILY			
Transmission, bevel gear and steering clutch compartment	Check oil level. Change oil if it becomes extremely dark in color and has started to thicken.	S3	
EVERY 250 SERVICE HOURS OR MONTHLY			
Transmission, bevel gear and steering clutch compartment	Change filter element — wash magnetic strainer	S3	•
Steering clutch brakes	Check — adjust if necessary		•
EVERY 1000 SERVICE HOURS OR 6 MONTHS			
Transmission, bevel gear and steering clutch compartment	Change oil and breather wash suction screen	S3	•
Universal joint and clutch brake	Lubricate three fittings	MPG	
WHEN REQUIRED			
Clutches	Require periodic maintenance that cannot be given a definite service hour interval. Maintenance information is given in the service manual.		•

KEY TO LUBRICANT

S3	— Superior Lubricants (Series 3) only.
HYD	— Superior Lubricants (Series 3) containing zinc dithiophosphate, MIL-L-2104A, MIL-L-2104B or approved industrial-type Hydraulic Oil.
MPG	— Multipurpose-type Grease
MPL	— Multipurpose-type Lubricant

LUBRICATION AND MAINTENANCE CHECKS ON A WHEEL LOADER WITH A POWER SHIFT TRANSMISSION AND STANDARD DRIVE AXLES

(Courtesy of Clark Equipment Co.)

HOURLY LUBRICATION & MAINTENANCE SCHEDULE

Warning: Except when specified, lower all attachments to the ground, apply the parking brake, shut down the engine, remove the ignition key, turn the disconnect switch to the "OFF" position, block the wheels, engage the articulation lock and tie a red warning flag on the canopy upright; when servicing the machine.

SYSTEM	OPERATION	TEXT LOCATION	HOUR INTERVALS					
			8	50	100	250	500	1000
Torque Converter Transmission	Check Fluid Level Daily, at the Transmission		●					
	Clean Torque Converter & Transmission Breathers			●				
	Replace the Filter Element					●		
	Check System for Leaks					●		
	Check Converter Out Pressure					●		
	Check & Adjust Transmission Shift Linkage						●	
	Drain and Refill Transmission, Converter, Winch, Hydraulic System						●	
	Check Transmission Clutch Operating Pressures						●	
Axle Prop Shafts and Wheels	Check Tire Pressures and Castings		●					
	Tighten Wheel Nuts & Inspect Rims			●				
	Check Fluid Level of Differential & Planetary			●				
	Clean Breathers						●	
	Drain and Refill Differential & Planetary							●
	Check for and Repair Drive Line Noises		●					

Courtesy of Clarke Equipment Co.

<table>
<tr><th colspan="2" rowspan="2">DRIVE LINE LUBRICATION</th><th rowspan="2">TEXT LOCATION</th><th colspan="6">HOURS</th><th rowspan="2">KEY</th></tr>
<tr><th>1000</th><th>500</th><th>250</th><th>100</th><th>50</th><th>8</th></tr>
<tr><td>27*</td><td>Universal Joints — 9</td><td></td><td>●</td><td></td><td></td><td></td><td></td><td></td><td>LBG</td></tr>
<tr><td>28</td><td>Split Joints — 3</td><td></td><td></td><td></td><td></td><td>●</td><td></td><td></td><td>LBG</td></tr>
<tr><td>29</td><td>Transmission, Converter and Winch</td><td></td><td></td><td>●</td><td></td><td></td><td></td><td>●</td><td>DX</td></tr>
<tr><td>30</td><td>Differential Check & Fill Plug (2)</td><td></td><td></td><td></td><td></td><td></td><td>●</td><td></td><td>EPGL</td></tr>
<tr><td>31</td><td>Differential Drain Plug</td><td></td><td>●</td><td></td><td></td><td></td><td></td><td></td><td>EPGL</td></tr>
<tr><td>32</td><td>Planetary Drain & Fill Plug</td><td></td><td>●</td><td></td><td></td><td></td><td></td><td></td><td>EPGL</td></tr>
<tr><td>33</td><td>Planetary Check Plug</td><td></td><td></td><td></td><td></td><td></td><td>●</td><td></td><td>EPGL</td></tr>
<tr><td>34</td><td>Pillow Block Grease Line</td><td></td><td></td><td></td><td></td><td></td><td></td><td>●</td><td>LBG</td></tr>
<tr><td>35</td><td>Pillow Block Seal Area (Repack)</td><td></td><td>●</td><td></td><td></td><td></td><td></td><td></td><td>DA</td></tr>
</table>

* — Locate these numbers on the diagram on the next page.

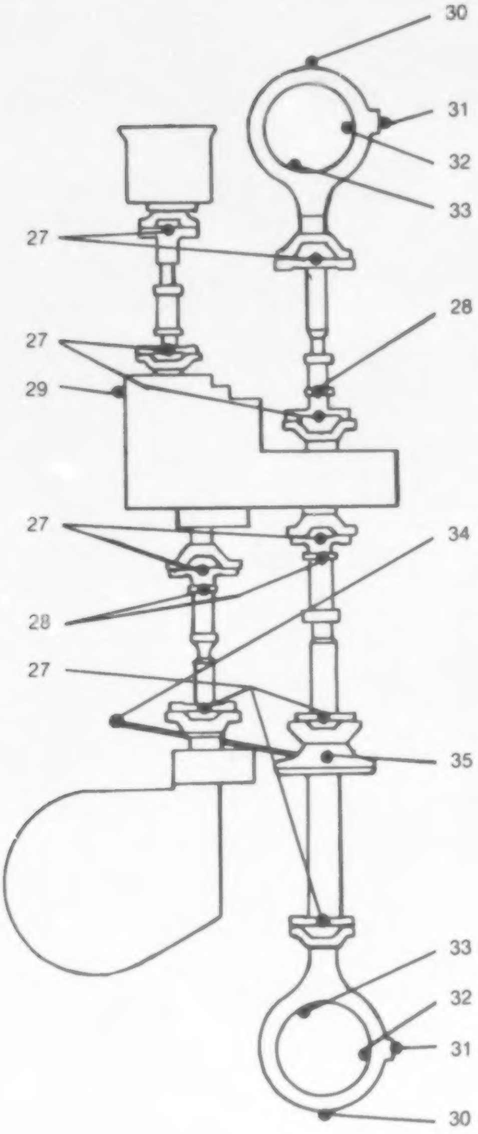
LUBRICATION KEY

<table>
<tr><td>LBG</td><td colspan="4">Lithium Base Multi-Purpose Grease
0°F. and above — Grade 2
Below 0°F. Grade 0</td></tr>
<tr><td>EPGL</td><td colspan="4">Extreme Pressure Gear Lube (* * SCL Type) SAE 75, SAE 90, or H-D-90</td></tr>
<tr><td rowspan="6">DX</td><td>Ambient Temp. Range</td><td colspan="3">Lubricant to be used</td></tr>
<tr><td rowspan="3">Above 0°F.
1)
2)</td><td>SAE Grade</td><td>API Class</td><td>Military Spec.</td></tr>
<tr><td>10W</td><td>+MS
DM</td><td>MIL-L-2104A, Supp. 1
or New MIL-L-2104B</td></tr>
<tr><td colspan="3">Dexron Automatic Transmission Fluid</td></tr>
<tr><td rowspan="2">Below 0°</td><td colspan="3">Dexron Automatic Transmission Fluid</td></tr>
<tr><td colspan="3">+ Sequence Tested</td></tr>
<tr><td>BA</td><td>Heavy Duty Brake Fluid</td><td colspan="3">SAE J 1703 or equivalent</td></tr>
<tr><td>DA</td><td colspan="4">Shell Darina "AX" Grease — Or Equivalent</td></tr>
</table>

* * "SCL" Signifies Sulfo-Chloro-Lead type. Factory fill is made with SCL type lube and it is recommended that the same type be used when adding or refilling.

Courtesy of Clarke Equipment Co.

DRIVE LINE LUBRICATION POINTS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(5-59)

Courtesy of Clarke Equipment Co.

SCHEDULED MAINTENANCE ON RETARDERS

In most cases hydraulic retarders are incorporated with either the engine oil lube system or the transmission oil system, so that when the oil is changed in either of these components the retarder's oil is also changed.

However, some retarders have their own supply of oil which should be serviced at recommended intervals.

Caution: On retarders wtih a self-contained oil supply be sure that the load control is in the released position before attempting to remove the reservoir cover. Failing to put the control in release could result in a shower of oil, hot oil if the machine has just been working.

REMOVING AXLE SHAFTS

Although you will not likely be involved with power train repairs at this level of training, you will probably have to remove axle shafts. For example, packing wheel bearings or removing wheels to do brake work requires removal of the axle shafts.

Removing a flange design full floating axle is a routine job that can be done without raising the vehicle. Remove the flange retaining bolts or nuts. The flange now has to be freed from the hub and lifted out by hand. Two quick methods of freeing the flange are:

1. Prying it loose with a screwdriver or
2. Striking the center of the flange one or two good blows. If the axle flange still resists, locate two tapped holes 180° apart (found on most axle flanges) that have no corresponding holes in the hubs. Thread two bolts into these holes with even pressure on each and the two bolts will push the flange free of the hub.

Whenever an axle shaft is removed always check it carefully for worn splines and signs of twisting. It is much better to replace a faulty axle while it's out than to have the axle break down shortly after its return to service.

A semi-floating axle is more difficult to remove. The vehicle has to be raised because the axle shaft not only supplies the torque but also supports the vehicle's weight. Remove the wheel and brake drum to gain access to the bearing retainers. In some cases part of the differential must be disassembled, as well, to get the shaft out. The axle shaft and bearing can then be pulled from the housing with a slide hammer puller. The bearing has to be pulled from the axle shaft (and installed) with a hydraulic press.

QUESTIONS — POWER TRAIN MAINTENANCE

1. What should a P.M. visual check of the power train include?
2. Clutch adjustment on a vehicle after a number of hours service is necessary to:
   (a) make it release easier
   (b) compensate for clutch disc facing wear.
   (c) smooth out clutch action.
   (d) make it release faster.
3. Before taking out a full floating axle, you first have to jack up the frame. True or False?
4. Briefly what should a scheduled maintenance of a power train include?
5. When servicing a power train component how do you know what type of grease or oil it uses?
6. Referring to the Lubrication Instruction for the Clarke Wheel loader, what type of oil does the differential use?
7. All retarders are self-contained hydraulic systems. True or False?
8. A properly adjusted clutch should have approximately ________________inches of free pedal travel.

ANSWERS — POWER TRAINS

1. (a) 2 (b) 3 (c) 1
2. 1. friction — clutch
   2. gears — transmission
   3. fluids — torque converter
3. True
4. Ratio is 4:1. Since the small gear travels four times faster, the speed of the larger gear is $\frac{6000}{4}$ = 1500 RPM.
5. A helical gear is stronger and runs quieter than a straight spur gear.
6. (d) ring gear, carrier and sun gear.
7. (e) both (b) and (d) are right.
8. The clearance between the two gear teeth at the pitch diameters.
9. More friction surface is obtained within the same diameter making a stronger clutch.
10. Clutch packs run wet and need a lining that won't be harmed by the oil. Most engine clutches run dry. Oil will contaminate dry clutch facings causing the clutch to slip.
11. 1. cheap to make
    2. positive (i.e., no slippage) once engaged
12. True
13. . . . stator.
14. Torque is divided over two or more shafts reducing loading on the gears, shafts and bearings. Therefore, the overall size and weight of the transmission can be reduced.
15. 1. planetary gear
    2. spur gear on parallel shafts
16. (b) manually
17. An auxiliary transmission increases the number of speed-torque ratios that the vehicle can travel at.
18. To allow the drive shaft to change length as the axle housings move up and down with respect to the frame.
19. Provides a gear reduction. Changes the direction of the power flow. Allows one wheel to turn faster than the other when turning a corner.
20. (d) Lock out differential action in poor traction conditions.
21. (b) dead and live.
22. A live axle is attached to the wheel and turns with it. A dead axle is stationary and the wheel turns on it.
23. A retarder absorbs torque whereas a converter transmits torque. A retarder will not stop a vehicle, it only assists the brakes in doing so.

ANSWERS — POWER TRAIN MAINTENANCE

1. Check for loose parts, oil leaks, and incorrect adjustments.
2. (b) Compensate for clutch disc facing wear.
3. False
4.
    1. Checking oil levels or changing the oil.
    2. Checking for loose parts, oil leaks and running adjustments.
5. Look it up in the service manual.
6. Extreme Pressure Gear Lube: SAE 75, SAE 90.
7. False.
8. . . . 1½ inches . . . .

TASKS — POWER TRAINS

CLUTCH AND CLUTCH BRAKE (If equipped)

ROUTINE MAINTENANCE CHECK

1. On a truck or tractor truck check and adjust the clutch clearance (and clutch brake if equipped) to manufacturer's specifications, using the correct tools and procedures outlined in the service manual.

MANUAL TRANSMISSION

ROUTINE MAINTENANCE CHECK

1. Check for and tighten any loose transmission bolts or components.

SCHEDULED MAINTENANCE

1. Drain the transmission oil, check and clean magnetic plugs, change the filter (if equipped) and refill with correct type and amount of lubricant (see service manual).
2. Check to ensure there are no leaks.

POWER SHIFT TRANSMISSION AND TORQUE CONVERTER

ROUTINE MAINTENANCE CHECK

1. Check for and tighten any loose transmission bolts or components.
2. Check for oil leaks and make any necessary minor repairs.

SCHEDULED MAINTENANCE

1. Drain the oil, remove and clean the filter housing and install a new filter. Refill the transmission with the correct type and amount of lubricant (see service manual).
2. Start the engine and ensure there are no oil leaks.

DRIVE LINE

ROUTINE MAINTENANCE CHECK

1. On a truck or tractor truck check and tighten any loose drive line bolts or components. Also check the drive line for wear at the universal joints, splines, steady bearings and mountings. Report any suspected unsafe operating conditions to a journeyman.

DRIVE AXLE

ROUTINE MAINTENANCE CHECK

1. Check and tighten any loose drive axle mounting bolts and components.
2. Check for oil leaks and make necessary minor repairs.

SCHEDULED MAINTENANCE

1. Drain the oil, check and clean magnetic plug, and change the filter (if equipped). Refill the drive axle with the correct type and amount of oil.
2. Check to ensure there are no oil leaks.

HYDRAULIC RETARDER

ROUTINE MAINTENANCE CHECKS

1. Check for and tighten any loose retarder bolts and components.
2. Check for oil leaks and make necessary minor repairs.
3. Inspect the reservoir, cooler, retarder and related hoses for leaks or damage and report to a journeyman if a suspected problem or an unsafe condition exists.
4. With the control valve in released position to prevent a shower of hot oil, check the oil level and fill if low.

BLOCK

6

Frames, Suspension, Running Gear and Working Attachments

BLOCK

6

Bearings and Seals

ANTI-FRICTION BEARINGS

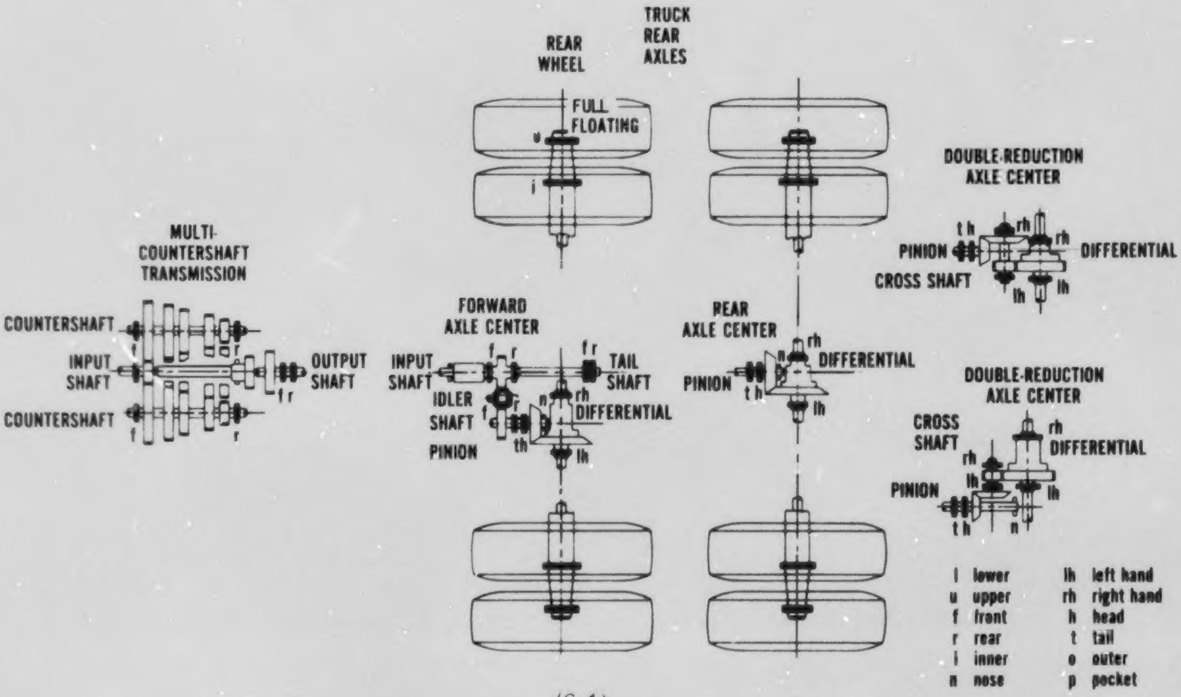
PURPOSE OF ANTI-FRICTION BEARINGS

Friction is the force or resistance generated when two objects are moved against one another. Since friction causes heat and wear, and thus damage, to surfaces in contact, ways must be found to reduce it. On a machine, anti-friction bearings are used to reduce friction between a shaft, wheel or gear that turns within a support. The bearings do this by providing a rolling contact for the surfaces. Lubrication further reduces the friction.

Anti-friction bearings perform the following functions:

- — allow parts in contact to move more easily
- — support a moving part and hold it in perfect alignment.
- — reduce the wear between moving parts
- — provide a replaceable wear surface. It is more economical to replace a bearing than to replace a shaft or a gear.

Figure 6-1 shows where bearings would be found in a typical tandem truck.


TRUCK REAR AXLES
REAR WHEEL
FULL FLOATING
u
i
MULTI-COUNTERSHAFT TRANSMISSION
COUNTERSHAFT
INPUT SHAFT
OUTPUT SHAFT
COUNTERSHAFT
f
r
f r
FORWARD AXLE CENTER
INPUT SHAFT
IDLER SHAFT
PINION
TAIL SHAFT
DIFFERENTIAL
f r
rh
n
th
lh
REAR AXLE CENTER
PINION
DIFFERENTIAL
rh
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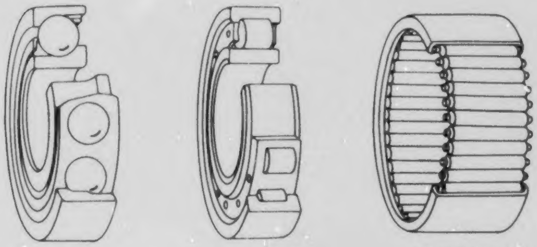
DOUBLE-REDUCTION AXLE CENTER
PINION
CROSS SHAFT
DIFFERENTIAL
t h
rh
lh
DOUBLE-REDUCTION AXLE CENTER
CROSS SHAFT
PINION
DIFFERENTIAL
rh
lh
t h
n
l lower
u upper
f front
r rear
i inner
n nose
lh left hand
rh right hand
h head
t tail
o outer
p pocket

(6-1)

Courtesy of Timkin Company

TYPES OF ANTI-FRICTION BEARINGS

Anti-friction bearings are used when low friction and exact alignment are required. There are numerous different types and sizes manufactured today, but they can be grouped into three basic designs: ball, roller, and needle (Figure 6-2). Ball and roller are the more common bearings. Needle bearings are used in compact spaces where extra stability is required. Bearing terminology is given in Figure 6-3.

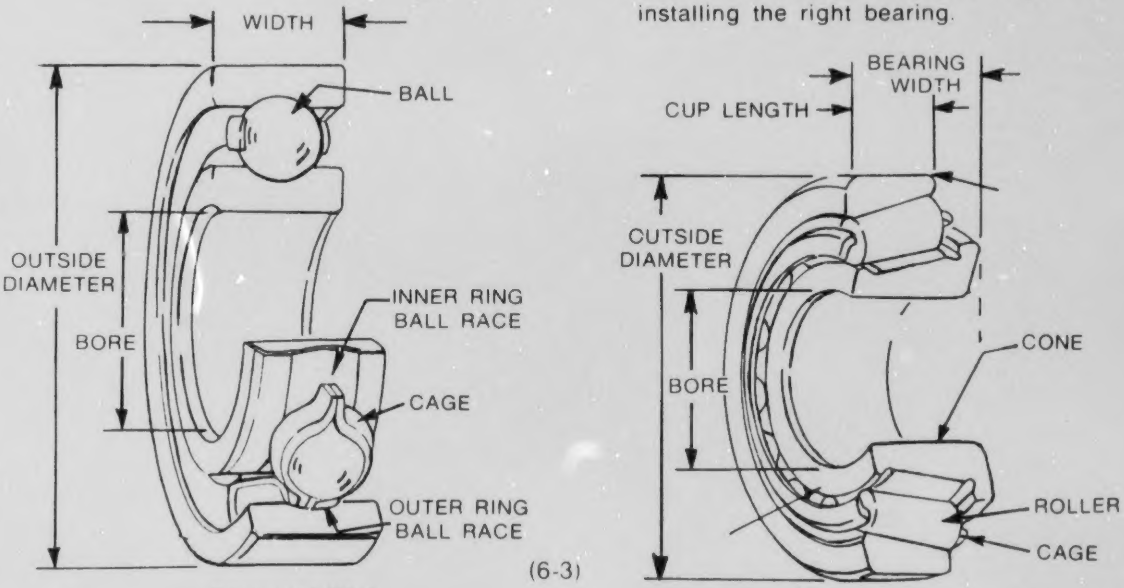

BALL BEARING
ROLLER BEARING
NEEDLE BEARING

(6-2) ANTI-FRICTION BEARINGS

Courtesy of John Deere Ltd

IDENTIFYING BEARINGS WHEN ORDERING REPLACEMENTS

1. Most bearings have a number or number/letter combination stamped on them. To order a bearing simply ask for that stamped number. There is no need to identify the bearing location. For example a bearing for a shaft in a generator could be stamped 62032RS. To order this bearing just request a 62032RS bearing.
2. Sometimes for one reason or another the stamped numbers are difficult to read. In this case, knowing the location of the bearing, look up the bearing number in the parts book. Note that parts books, as well as giving part numbers, also show the relationships of the parts by means of exploded view diagrams.
3. A general rule when ordering any part is to err on giving too much information, rather than not enough and then receiving the wrong part.
4. Always save the bearing being replaced so that you can compare it with the new one. In this way you will be sure you are installing the right bearing.



(6-3)

BALL BEARING

TAPERED ROLLER BEARING

BEARING CAPACITIES

Bearings are built with different capacities or load ranges.

Bearing capacity is determined by many factors, most of which are not visible and cannot be appraised without special equipment. In general, though, the capacity of a bearing depends on:

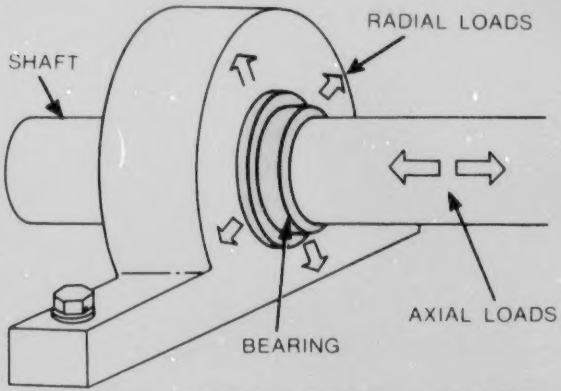
- size of bearing
- number of rolling elements
- type of races.

RADIAL AND AXIAL LOADING ON BEARINGS

Each type of bearing is designed to do a specific job. One of the main factors affecting the design of a bearing is whether the bearing takes a radial or an axial load. A radial load is a load carried at right angles to the rotating shaft. An axial load (also called a thrust load) is a load or a thrust parallel to the shaft. Radial loading is a force acting vertically, while axial loading is a force acting horizontally.

An example will illustrate the difference between the two kinds of loads. When a car is running straight on a road the wheel bearings take an up-and-down radial load. When the car turns a corner there is a sideways or horizontal thrust on the wheel bearings and the load shifts to an axial load.

Some bearings are designed to take mainly radial loads (e.g., straight roller bearing), some to take only axial loads (i.e., ball thrust bearings) and others to take combinations of axial and radial loads (e.g., tapered bearings).



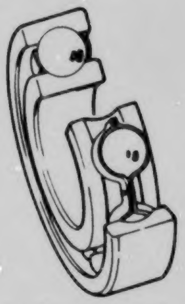
(6-4) LOAD FORCES ACTING ON BEARINGS

Courtesy of John Deere Ltd.

SIX COMMON TYPES OF BEARINGS

Single Row Deep Groove Ball Bearings

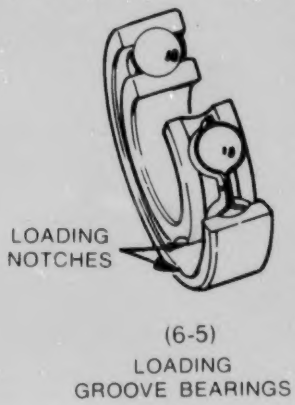
The single row deep groove ball bearing (also called "limited", non-loading groove and "conrad" type) has one row of balls rolling in a single, deep groove in each race. Because of the height of the lands and the close fit of the balls to the grooves, these bearings can stand a substantial thrust load even at very high speeds. Careful installation is necessary as these bearings demand more careful alignment between the shaft and housing than self aligning bearings. Single row deep groove ball bearings are used for radial loads and radial-thrust combinations. Because there is little relative movement between the inner and outer races, these bearings are often equipped with seals and shields, to exclude dirt and retain lubricant.



(6-5) DEEP GROOVE BEARINGS

Loading Groove Ball Bearings

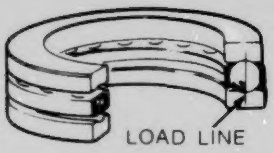
Ball bearings manufactured with loading grooves (known as "maximum" type (have a high radial capacity because they have many balls between the races. However, they are not as tolerant of thrust loads.



(6-5)
LOADING
GROOVE BEARINGS

Ball Thrust Bearings

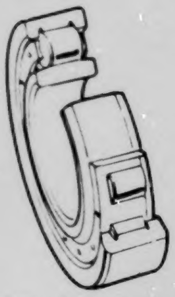
Ball thrust bearings are designed for axial thrust loads only. The load line through the bearing balls is parallel to the shaft resulting in high thrust capacity and minimum axial displacement.



(6-5) BALL THRUST BEARINGS

Straight Roller Bearings

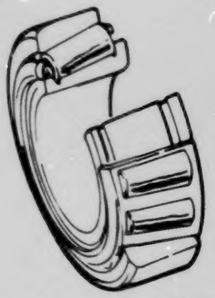
Straight roller bearings have very high radial capacity, but low tolerance for misalignment or thrust loads. They may be operated at high speeds. Those which have locating ribs on only one race allow for some axial movement of the shaft in relation to the housing and are easy to dismount, even if both rings are "press fit". They are sometimes made with two or more rows of rollers.



(6-5) STRAIGHT BEARINGS

Tapered Roller Bearings

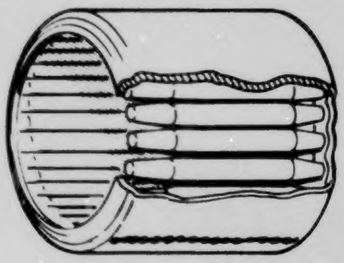
Tapered roller bearings are constructed so that the roller centerlines and raceway surfaces form an angle with the shaft centerline. They are, therefore, suitable for carrying heavy combined radial and thrust loads. They are separable — the cup is mounted separately from the cone (inner race and rollers). Tapered roller bearings are usually installed in pairs with one bearing facing the other and both bearings must be adjusted for preload or clearance.



(6-5) TAPERED BEARINGS

Needle Bearings

Needle bearings are constructed of a series of small diameter rollers, or needles, often in a formed shell. Usually there is no inner race, and sometimes no outer race or shell as the needles run directly on the shaft or housing or inside the gear hub. They are usually used only for light load, no thrust applications. Some have rather high internal friction because no separator is used to keep the needles from rubbing against each other. Needle bearings are used mostly to align or guide shafts, or to separate shafts where one is inside another or where one is piloted into another. However, there are some applications, particularly where space is at a premium, where special-made, extremely high capacity needles are used for heavy radial loads. Needles used in these heavy applications are of a size and/or hardness to classify them with roller bearings.



(6-5) NEEDLE BEARINGS

LUBRICATION OF ANTI-FRICTION BEARINGS

Lubrication is essential to the proper performance of anti-friction bearings. The kind of lubricant used is governed by the design of the bearings, the bearing load, and the conditions the equipment is being operated under. Lubricants perform the following functions for bearings:

— carry away heat

— protect bearing surface from rust and corrosion

— reduce friction between the bearing and its load.

Bearings are lubricated by either a grease or an oil. Grease is used when a thickened lubricant is required mainly to overcome seal leakage, for example, in a wheel bearing. Oils are used where a more liquid lubricant is required. The oil must be contained by a housing and requires a good seal. The oil is distributed to the bearing by splash or by pressure feed.

PRELOAD ON ANTI-FRICTION BEARINGS

Preload is a load put on a tapered roller bearing prior to the bearing taking on its actual working load. On some tapered roller bearings the preload is built in, while on others the preload must be adjusted. The means of adjustment is usually a threaded locking device or shims.

Preload maintains exact alignment of a shaft or gear. By making the rolling elements of the bearing lay flat on the inner and outer races, preload ensures that the load is carried evenly and not just on the inner or outer ends of the rollers.

Adjusting the preload is a very important service procedure when installing tapered roller bearings. Specific adjustment procedures will be clearly stated in the service manual.

REMOVAL AND INSTALLATION OF BEARINGS

Bearing Fit

Ball and roller bearings are usually installed with either the inner ring or the outer ring a tight fit. If the inner ring is a tight fit it means that the bore of the ring is slightly smaller than the shaft diameter and some force is needed to remove or replace it. If the outer ring is a press fit in the housing, as in a wheel hub bore, the outside diameter of the ring is slightly larger than the housing bore.

This fit or interference usually amounts to a few ten-thousandths of an inch (.0001″) in the case of small bearings; to several thousandths in the case of large bearings.

Certain bearings are applied with tight fits on both rings and some with a loose fit on both rings.

Tools For Removing Bearings

An arbor press, a hydraulic press, various kinds of pullers, or some improvised tools can be used to remove a bearing. An arbor press and a hydraulic press are generally used to remove bearings in a shop; while pullers or a portable hydraulic press are used to remove bearings in the field. Whichever tool is used the object is to remove the bearings without damaging the bearing or the shaft. The bearing may be perfectly serviceable and can be reinstalled in the machine. Even if a bearing is to be thrown away, it should still be pulled or pressed out correctly as there is a danger of a bearing exploding if it is carelessly removed.

Prior To Removing A Bearing

Wash off the bearing housing, taking care to keep loose dirt from getting into the housing.

Take a few moments to study the assembly and determine the best way to undertake bearing removal.

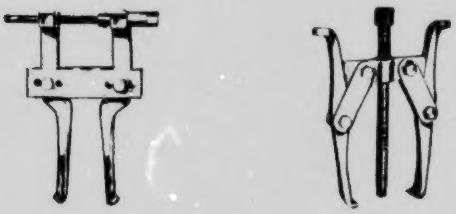
REMOVAL OF BEARINGS

General Rules For Removing Bearings

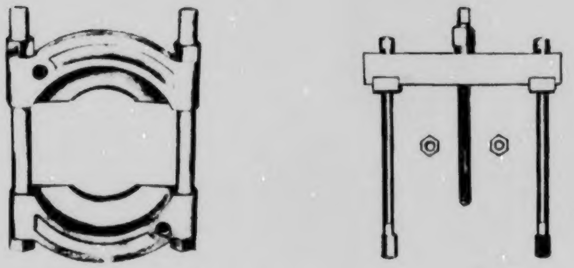
These rules apply whether using an arbor press, a hydraulic press (shop or portable), or pullers.

1. Press or pull wherever possible only on the ring which is tight.
2. Press or pull straight and square to keep the ring from cocking which might score the shaft or housing and could damage the bearing.
3. Never press or pull against bearing dust shields or cage.

Various types of pullers are shown in Figure 6-6.

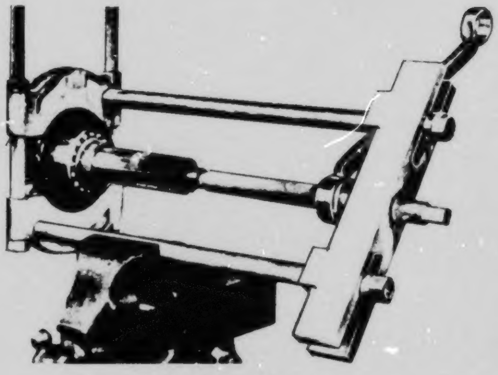


(6-6)



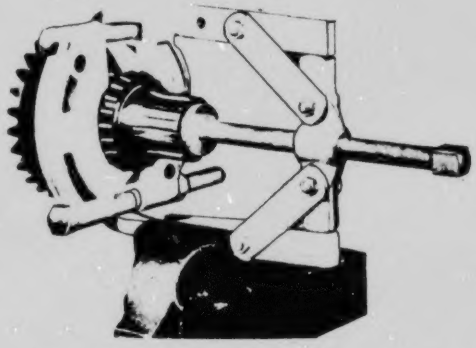
Typical bearing pullers which may be used separately or in various combinations to pull or push complete bearings or individual rings

(6-6)



Adjust tools to pull bearings straight and square

(6-6)



Where there is enough space behind a bearing or bearing ring to admit a puller, always be sure that the puller is adjusted so that it will not slip over the inner ring when pulling pressure is applied. If this happens, bearing parts can be severely damaged.

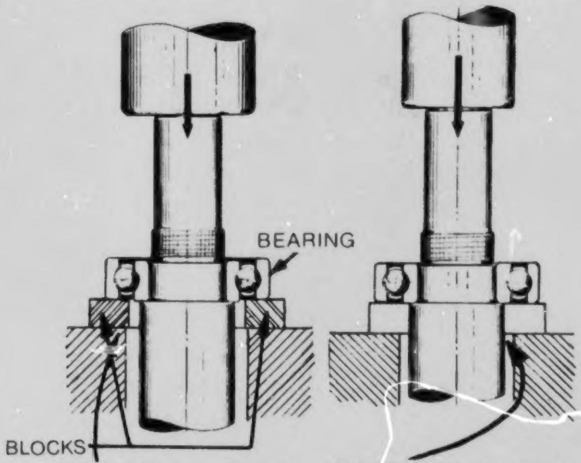
(6-6)

Removing Bearings With Arbor and Hydraulic Presses

Figure 6-7 shows the right and wrong methods of removing a bearing with an arbor or hydraulic press. The press ram is pushing down against the shaft on which the bearing inner ring is tightly fitted. The stripping is being done by the support blocks under the rings. The blocks must be the same size and squared on all sides.

Note, as shown in the wrong method that if the support blocks are spaced too far out the pressure will be against the outer ring or shield. Damage will result as a heavy stress is put on the balls or rollers which can injure them and cause indentation of both races.

Keep the press table and the blocks clean and square. Provide some means to keep the shaft from falling to the floor. If the shaft and bearing are very large and the shaft end cannot be squared up with the press ram, turn up two steel blocks to make a self-aligning fixture between the ram and the shaft. Protect the end of the shaft with a pad of lead, copper or other soft metal.



WRONG — Blocks contact the bearing outer ring only.

RIGHT — Blocks contact inner ring — or both rings if bearing is flush faced.

(6-7)

ARBOR PRESS

HYDRAULIC PRESS

(6-8)

Improvised Tools For Removing Bearings

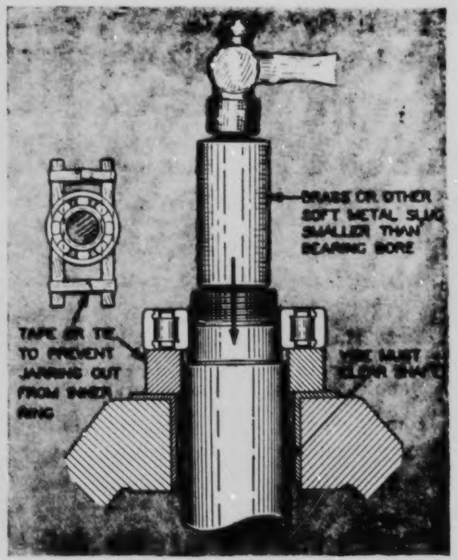
Using proper care, bearings can be removed quite safely with improvised methods when the right tools are not available (Figure 6-9).

A vise will do instead of an arbor press and a drift will take the place of the press ram. If the shaft is held in the vise, protect its surface with copper sheet or by hardwood blocks.

When using a tube, drive alternately on one side and then the other to keep the bearing from cocking.

If it becomes necessary to remove a bearing by pressure not directly applied to the tight fitting ring, do not pound it off; use a puller or pry it off exerting even pressure.

Sometimes a separable inner ring is installed against a shoulder of equal diameter so that there is no way to get hold of it. Leave the bearing ring on if it is usable. If not, cut it off with a torch. Burn it part way through in order not to harm the shaft. It may loosen enough to pull off. If not, crack it through the rest of the way with a hammer and cold chisel, using precautions to prevent personal injury by flying parts.


BRASS OR OTHER SOFT METAL SLUG SMALLER THAN BEARING BORE
TAPE OR TIE TO PREVENT JARRING OUT FROM INNER RING
VISE MUST CLEAR SHAFT

To drive shaft out of bearing, use a soft metal slug which will not mar the shaft.

(6-9)

BEARING REPLACEMENTS

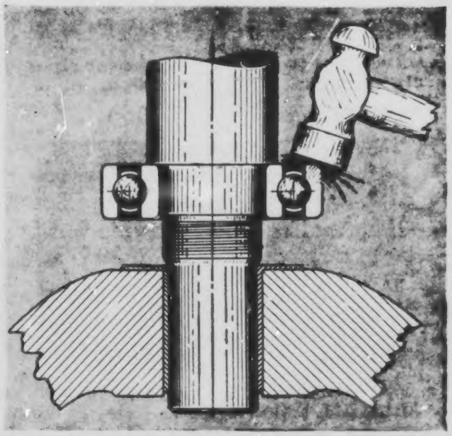
As a rule when bearings are taken out they are discarded and new ones installed. It is more economical to replace a bearing while a machine is down than to reinstall the used one, even though the used bearing may still be serviceable. The reasoning is simple: a new bearing contains more serviceable hours than a used one. Another consideration is that it makes more sense to replace a bearing than to risk damage due to bearing failure to the more expensive part the bearing supports.

Note: Save the used bearing to compare it with the new one so that you can be sure you are installing the right bearing.

When removing a bearing that has failed, take a half a minute to examine the bearing for the cause of failure. Some of the signs to look for are:

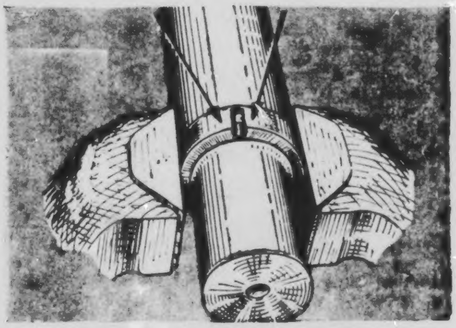
1. metal fatigue — bearing has worn out; it ran over its serviceable life.
2. scored or scratched rolling elements and/or races — dirt contamination possibly suggesting poor preventive maintenance, or metal chip contamination indicating internal damage.
3. darkened or burned metal — overheating caused by lack of lubrication.
4. roller taper bearings worn on small diameter — the bearings were adjusted too loose.

   roller taper bearings have darkening or excessive wear on large diameter — the bearings were adjusted too tight.
5. rust, corrosion — the bearings were not lubricated properly.



Never pound directly on a bearing or ring. It will likely damage both shaft and bearing.

(6-9)



If ring has been cut to remove, squeeze in vise and strike smartly at points indicated to fracture it. Be careful of shaft.

(6-9)

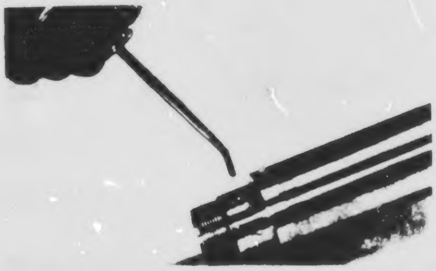
INSTALLATION OF BEARINGS

General Practices When Installing Bearings

1. Clean shafts and bearing housings thoroughly.
2. Clean dirt out of keyways, splines and grooves. Remove burrs and slivers.
3. Clean and oil bearing seats.
4. Press bearings on straight and square.
5. Press only on the ring which takes the tight fit.
6. Press bearings until they are seated against the shaft or housing shoulder. (See Figures 6-10 and 6-11.)

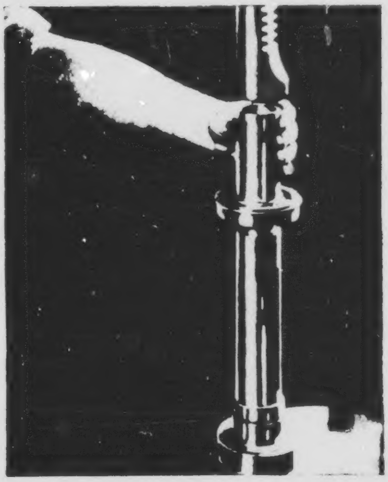
Bearing installation is just the reverse of bearing removal. Use an arbor press if available and press the shaft into the bearing, supporting the inner ring on blocks as shown in the sketch. Be sure the blocks don't scrape the shaft or threads.

If the distance between the end of the shaft and the bearing seat is fairly short, hold the shaft in a vise and press the bearing onto the shaft with a clean tube. This can be done either in an arbor press or by tapping with a hammer evenly around the tube.



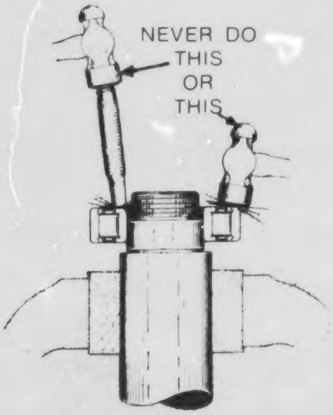
A small amount of oil on bearing seat eases mounting — helps prevent shaft scoring.

(6-10)



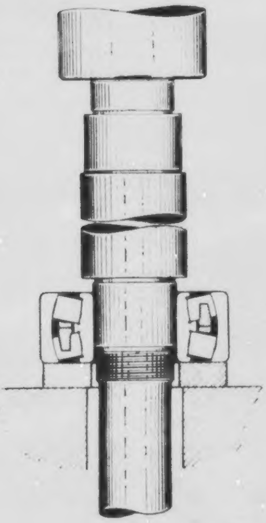
Using tubing with squared ends to avoid cocking bearing. Center it before pressing.

(6-10)



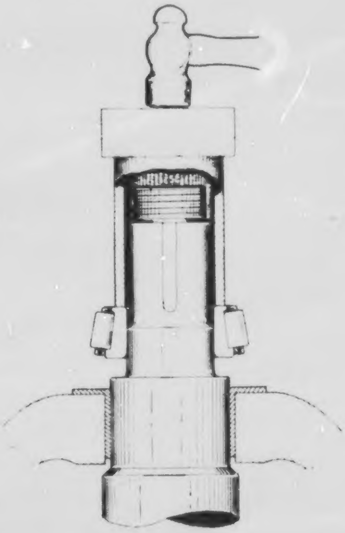
Never use a hammer direct on any bearing; it will result in damage.

(6-11)



Be sure blocks will clear threads before forcing shaft into bearing.

(6-11)



A tough hardwood block used like this is O.K. — protects end of tube.

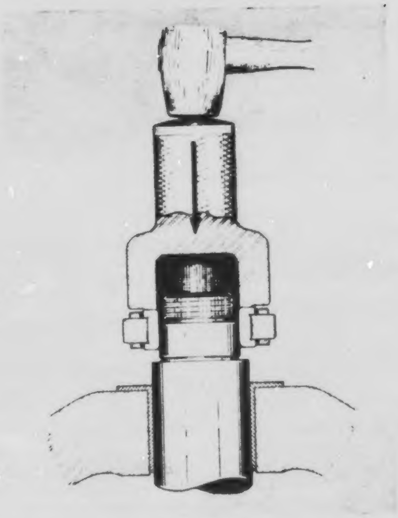
(6-11)

If the end of the shaft is flush with the bearing, use a drift or bearing installer. These are made with flat ends to use with shafts which are flush with the bearing and with counterbores, as shown at the right, to use where the shaft projects beyond the end of the bearing for a short distance. Tap lightly at first to make sure the bearing or ring goes on square and does not scrape or burr the bearing seat. Be sure bearing is tapped to a firm seat against the shaft shoulder.

Do not leave bearings exposed in partial assemblies (Figure 6-12). Cover the bearings until ready to complete the assembly, to prevent damage by moisture, dirt or other foreign matter. Any clean cloth or paper will do so long as the bearings are well covered.

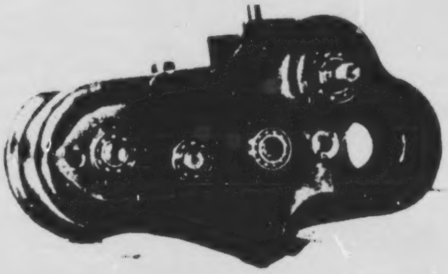
The inner rings of large bearings are generally shrunk on shafts. This is a very simple operation consisting of heating the bearing or inner ring in clean oil or temperature controlled oven to a temperature of between 200 and 250 F. (Figure 6-13). This expands the inner ring sufficiently so it should slip over the shaft to the bearing seat. Don't overheat the bearing or it will lose its hardness. Equipment and methods as shown on preceding page are still advisable for best results.

If expanding the ring is not enough to get it on, freeze the shaft in dry ice to make it shrink smaller.



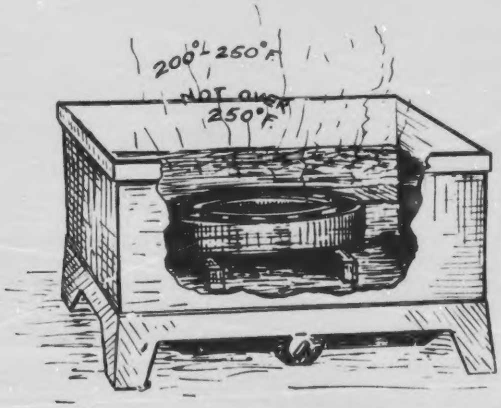
After bearing is on far enough to align itself with shaft, drive to firm seat against shoulder.

(6-11)



Bearings in partial assemblies like this will collect harmful dust or dirt if left standing too long.

(6-12)

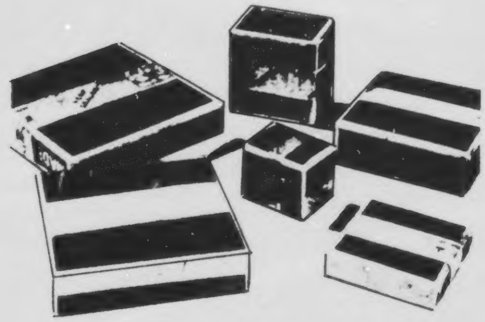

200°L 250°F.
NOT OVER 250°F.

Support bearing on blocks, well away from bottom. Don't keep bearings in hot oil or oven after correct temperature is reached.

(6-13)

Good Practices When Handling Bearings (Figure 6-13)

1. Keep bearings in original cartons or wrappings until ready for use. If a package is opened and the bearing is not used immediately, protect it by re-wrapping.
2. Keep the bearings clean and away from moisture.
3. Don't scratch or nick bearing surfaces.
4. Handle bearings with clean hands and use clean tools. Handle bearings as little as possible. Finger marks are hard to wash off and perspiration starts corrosion.
6. Don't take new bearings apart. They were assembled correctly in the first place.
7. Don't spin any bearings with compressed air.

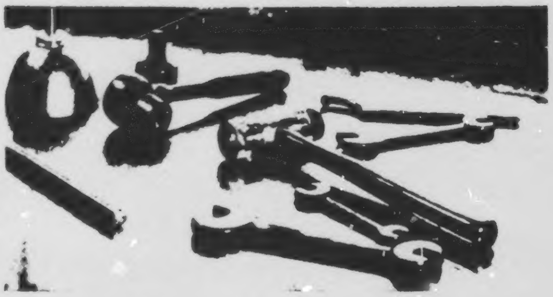


Keep bearings in their original boxes and wrappings until they are to be mounted.

(6-13)

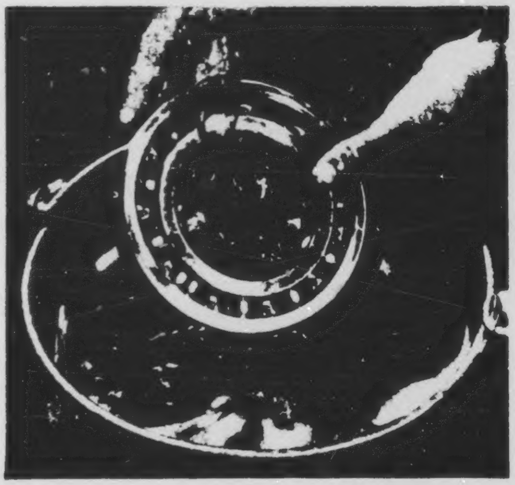
Clean hands plus clean rags mean cleaner bearings and less chance of corrosion from perspiration.

(6-13)



Get the habit of wiping tools and work benches. Clean tools are "half the battle" in keeping bearings clean.

(6-13)



Never wash the grease oil out of new bearings. It is carefully selected and put there for bearing protection.

(6-13)

METHODS OF LUBRICATING ANTI-FRICTION BEARINGS

Anti-friction bearings are lubricated by:

1. a grease gun, e.g., a pillow block bearing such as the one in figure 6-4.

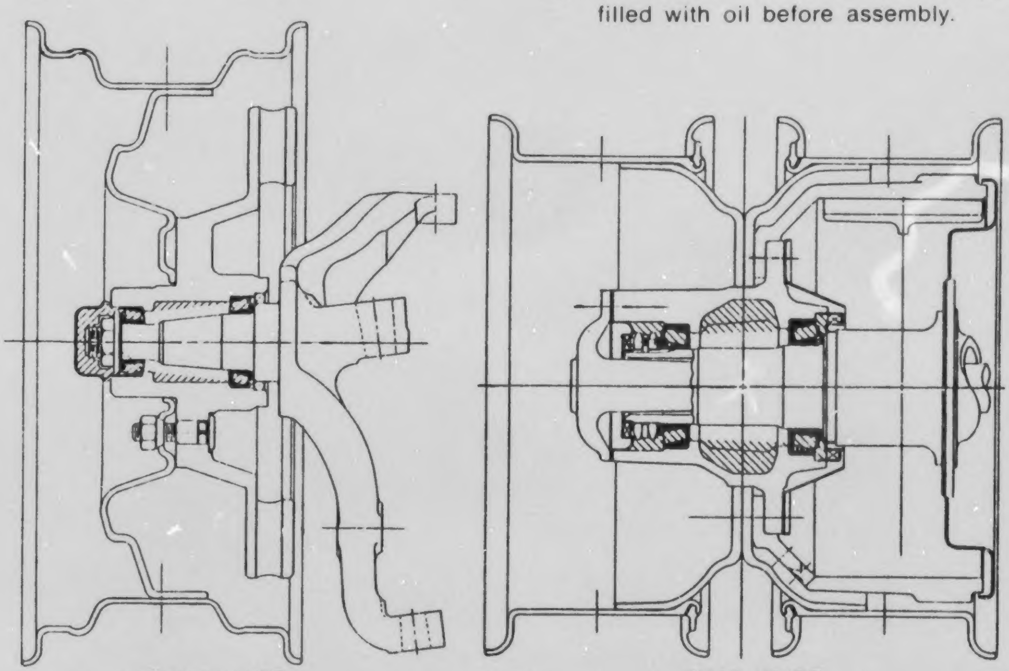
   Note: Grease guns are used less and less as more bearings are pregreased and sealed by the manufacturer.

2. packing with grease (the bearing can be packed by hand or it can be prepacked and sealed by the manufacturer), e.g., wheel bearings.
3. splashing or pressure feeding oil contained in a housing, e.g., transmission bearings.

The frequency of lubrication is determined by the load a bearing carries, the speed it moves and the temperature it operates under. For example, a wheel bearing may not require lubricating as often as a pillow block bearing used on a conveyor roller. Service Manuals will give bearing lubricating schedules.

Good Lubricating Practices

1. Consult the service manual for lubrication schedules and for the correct type and amount of lubricant to use.
2. In a splash system check the oil level regularly. Also inspect seals and vents regularly.
3. Clean the grease nipple before applying the gun. Clean the oil cap before removing it.
4. Don't overfill. Too much grease or oil can be just as harmful as too little. If overfilled, grease or oil will ooze out of the housings past the seals and enclosures, collect dirt and cause problems such as overheating. The churning of overfilled lubricant, particularly on high speed bearings, will cause the bearing to run excessively hot and will result in it failing prematurely.
5. When a wheel bearing is properly packed the grease will completely fill the area around the rolling elements of the race. With the hub properly cleaned, place enough grease in the hub to fill the area between the inner and outer cups as shown by the shading in figure 6-14. This will act as a dam to prevent the grease in the bearing from running out when heated in operation. Set the inner bearing into the hub and install the grease seal. The wheel assembly should then be installed on its shaft, the outer bearing installed and adjusted.
6. On oil hubs, the hub must be partially filled with oil before assembly.



FRONT WHEEL (6-14) REAR WHEEL

Courtesy of Timkin Company

BEARING ADJUSTMENT

Tapered roller bearings must be adjusted to give the bearing the correct running clearance or pre-load and then must be locked into position. Below are some common bearing adjusting devices. The list is intended to give a general idea of bearing adjustments. Service manuals will give the exact procedures for how to adjust specific bearings. Always use a torque wrench to get an accurate adjustment.

Common Bearing Adjusting Devices

1. Slotted hex nut, cotter pin, on a threaded shaft, e.g., front wheel bearings on automobiles or light trucks.

   Method of adjusting:

   rotate the wheel, tighten nut till slight bind, back off nut, lock the nut with the cotter pin.

2. Two standard lock nuts and a tongued washer, e.g., highway trailer wheels.

   Method of adjusting:

   rotate the wheel, tighten the adjusting nut until a slight bind, back off adjusting nut, tighten the jam and lock nut.

3. End cap and shims — e.g., transmission bearings and axle carrier bearings.

   Method of adjusting:

   (a) A shim pack is selected that will give the correct bearing running clearance.

   (b) Or sufficient shims are removed or added to give a slight bind or preload on the bearings.

   The end cap is locked with cap screws and lock washers or lock wires.

4. Threaded cup followers, cap screw and locking plate, e.g., differential bearings:

   Method of adjusting:

   adjust the follower to specified clearance and lock the follower by sitting the plate in the lugs or holes in the follower.

BEARING TERMINOLOGY

(Courtesy of International Harvester Co. of Canada Ltd.)

Axial — parallel to the shaft or bearing bore.

Carburizing — addition to metal of the element carbon for hardening purposes.

Case harden — hardening the outer surface of metal to a given "case" or "shell" depth, while leaving the inner portion "soft" to absorb shocks and squeezing (see carburizing).

Creep — the very slow, steady rotation of a "push fit" bearing race, either inner or outer, in order to constantly keep changing the area of greatest load, to increase bearing life. "Push fit" bearing races creep because of the squeezing action of the bearing balls, causing the relatively loose push fit race to act like a cam and propel itself around and around its mounting. Remember that one rotation of a race by creep may result only after several thousand revolutions of the rest of the bearing.

Crowned — a very slight curve in a surface (may be on a roller or raceway).

Deflection — bending or movement away from normal due to loading.

End play — (Axial displacement) — that amount of axial movement in a shaft due to clearance in the bearings.

End shake — end play (see above) within a bearing.

Heat treatment — heating, followed by fast cooling to provide required hardness or metallurgical structure.

Loading grooves — filling notches machined into side of races to permit loading of more balls or rollers.

Load line — a centerline indicating the points of contact within a bearing through which the load would pass.

Load line angle — the angle of a load line with respect to the shaft center or bearing radial centerline.

Misalignment — when bearings are not on the same centerline within good functional or working limits.

Pre-load — a load within the bearing, either purposely built in, or resulting from adjustment.

Press fit — mounting with interference, i.e., bore of bearing is smaller than OD of shaft, or OD of bearing is larger than bore of housing, or both.

Push fit — this means that the part of the bearing termed "push fit" can be slid into place by hand, if it is square with its mounting.

Raceway — the surface of the groove or path on which the balls or rollers of a bearing roll.

Radial — perpendicular to the shaft or bearing bore.

Radial clearance — (Radial displacement) — clearance within the bearing and between balls and races perpendicular to the shaft.

Radial load — a "round the shaft" load, that is, one that is perpendicular to the shaft — through the bearing.

Separable — either the inner or outer race or both may be removed from the bearing assembly.

Spherical — ball-like, rounding, or like a portion of a ball.

Thrust load — a load which pushes or reacts through the bearing in a direction parallel to the shaft.

QUESTIONS — BEARINGS

1. Name three main purposes of anti-friction bearings.
2. What are the two load forces acting on bearings? Describe them.
3. What are three basic types of anti-friction bearings? Give the type of load each will carry.
4. If the stamped number is not readable on a used bearing, how would you go about ordering a new one?
5. The general rule is to ________ bearings when they are taken out.
6. What are the three factors that govern the capacity of a bearing?
7. How do tapered roller bearings differ in their load carrying ability from straight roller or ball bearings? Give two examples where tapered roller bearings are commonly used.
8. What three functions must a lubricant perform for bearings? Where would grease be used instead of oil to lubricate a bearing?
9. Referring to tapered roller bearings, what does the term pre-load mean? Why is it necessary?
10. What tools are commonly used to remove bearings in a shop? In the field?
11. Where should the stripping blocks be placed when removing a bearing with an arbor press?
12. If a bearing is press-fit on a shaft, at what point would you apply pressure to remove it?
    - (a) the outer race
    - (b) the inner race
    - (c) either the inner or outer race; there is no difference
13. True or False? Grease bearings liberally; extra grease won't hurt them.
14. A small amount of __________ on a bearing seat makes mounting the bearing easier and helps prevent shaft scoring.
15. True or False? It's an acceptable practice to spin dry bearings with compressed air.

ANSWERS — BEARINGS

1. Support a moving part.

   Reduce friction.

   Reduce wear between moving parts.

   Provide a replaceable wear surface.

2. Radial load — a load acting at right angles to the shaft.

   Axial (thrust) load — a load acting parallel to the shaft.

3. Ball bearing — radial and some axial or thrust loading depending on the particular bearing construction.

   Roller bearing — basic straight roller bearing carries only radial loading. Tapered roller bearings carry radial and axial loads.

   Needle — radial loading, or axial depending on how it is made.

4. Knowing the location, look up the bearing number in the parts book.

5. . . . . replace . . .

6. Size of the bearing

   Number of rolling elements

   Type of races

7. Tapered roller bearings carry heavy, combined radial and axial (thrust) loads. They are used in:

   wheel bearings
   final drives
   drive axles
   transmissions
   steering gears

8. The lubricant must:

   — carry away heat from the bearing
   — protect the bearing surface from rust and corrosion
   — reduce friction between the bearing and its load.

   Grease is used mainly to overcome leakage in places where oil would be difficult to contain.

9. Pre-load is a load put on tapered roller bearings prior to the bearing taking on its actual working load.

   It makes the rollers lay flat on the inner and outer races to ensure that the load is carried evenly and not just on the inner or outer ends of the rollers.

10. Shop — arbor press, hydraulic press

    Field — pullers, portable hydraulic press

11. Under the inner ring close to the shaft.

12. (b) the inner race

13. False.

14. . . . . oil . . .

15. False. Never spin bearings with compressed air.

SEALS

PURPOSE OF SEALS

Wherever metal parts fit closely together and one part turns within the other, e.g., a shaft extending from a transmission case, something is needed to keep the oil from leaking out and to prevent dirt from entering the case. The metal parts could be made precisely enough so that no fluid would leak, but this kind of precision would be too costly to manufacture. Thus the need for seals.

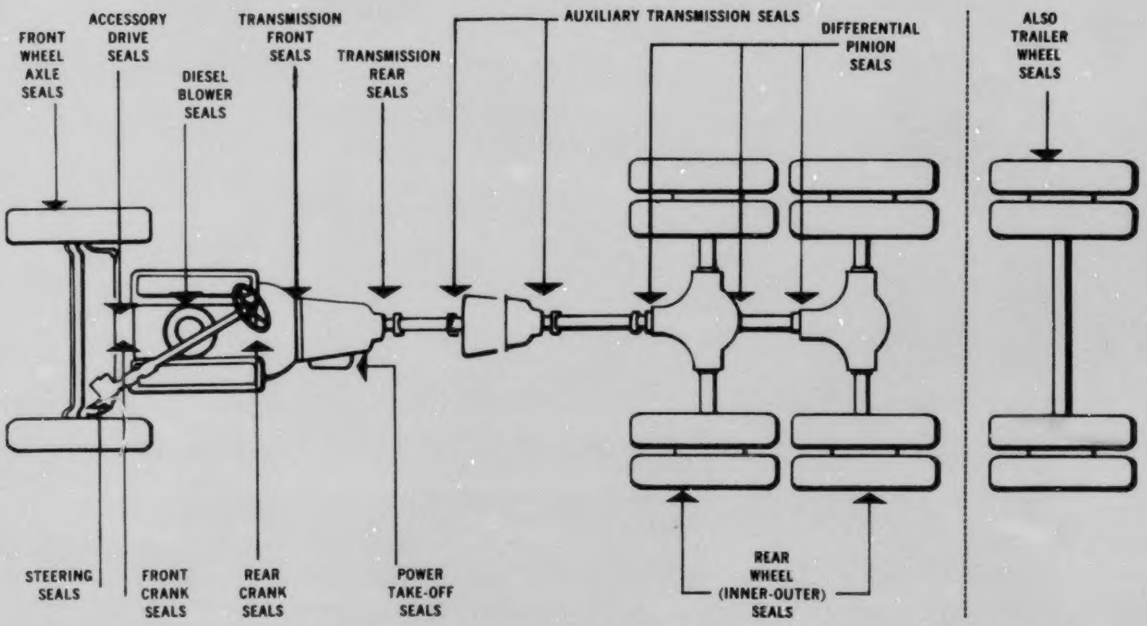
Seals are essential parts of modern machinery. For example, the seal in the hydraulic cylinder of a dozer holds the oil under pressure allowing the blade to be raised and lowered. Seals are necessary to seal in the fluid in the brake system, or, if the brakes are power assisted, to seal the vacuum chamber.

Seals are required to do one of the following jobs:

1. Retain fluids
2. Exclude dirt.
3. Hold a pressure.
4. Hold a vacuum.

Figure 6-15 shows the location of grease seals most often replaced in tractors, trucks, trailers, and buses.

GREASE SEALS IN TRACTORS, TRUCKS, TRAILERS AND BUSES


FRONT WHEEL AXLE SEALS
ACCESSORY DRIVE SEALS
DIESEL BLOWER SEALS
TRANSMISSION FRONT SEALS
TRANSMISSION REAR SEALS
AUXILIARY TRANSMISSION SEALS
DIFFERENTIAL PINION SEALS
ALSO TRAILER WHEEL SEALS
STEERING SEALS
FRONT CRANK SEALS
REAR CRANK SEALS
POWER TAKE-OFF SEALS
REAR WHEEL (INNER-OUTER) SEALS

(6-15)

Courtesy of C.R. Industries

TYPES OF SEALS

There are two basic types of seals:

1. Dynamic seals — used to seal moving parts, e.g., wheel seals.
2. Static seals — used to seal stationary parts, e.g., gasket.

It's inaccurate to think of seals as being simple parts. Many complex factors are considered in designing a seal, factors such as:

- What pressures on the seal are expected (if any)?
- At what temperatures will the seal operate?
- Is the seal material compatible with the fluid it will seal?
- Will the seal fit sufficiently tight to do its job without wearing too rapidly or causing excessive friction?
- Will the seal material score or scratch the polished metal surface?
- Will there be flexing as well as rotary or axial movement of the part?

Since each seal is designed to do a specific job, replacement seals must be the exact type shown in the manufacturer's parts book. Note that seals are usually harder to identify than bearings because the numbers on a removed seal are often very faint or completely unreadable. Always check a new seal carefully to be sure it is the right one, i.e., it's outside and inside diameter, width and sealing surface.

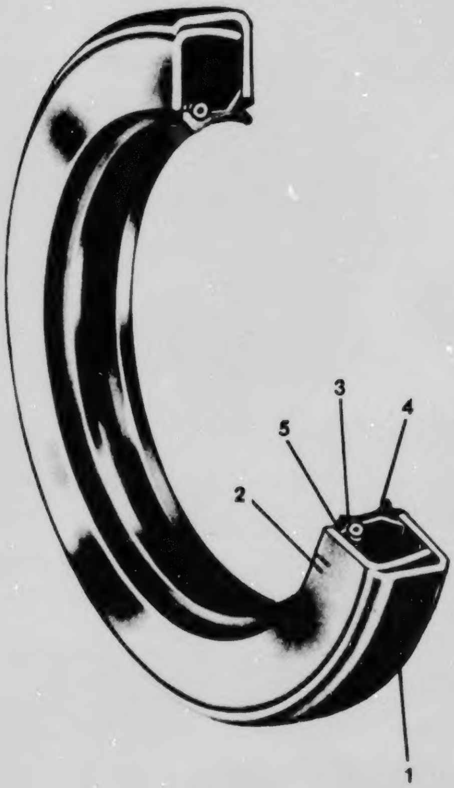
DYNAMIC SEALS

Six types of dynamic seals are:

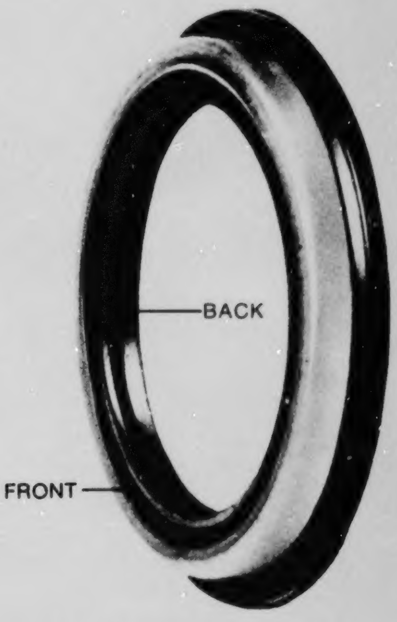
1. Radial lip seals.
2. Exclusion seals.
3. Metal ring seals.
4. Metal face seals.
5. Compression packings.
6. O-rings.

Radial Lip

Radial lip seals generally are used to seal revolving shafts which extend from housings containing fluids. They are usually called rotating shaft seals. A typical lip seal is shown in Figure 6-16.

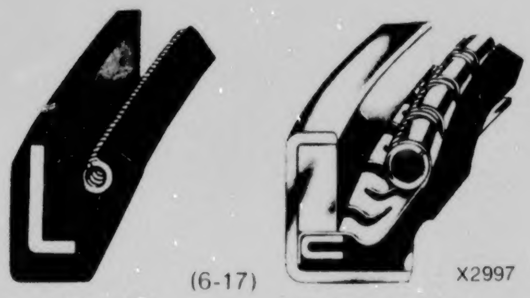


1 Outer metal shell
2 Inner metal shell
3 Steel garter spring
4 Auxiliary dirt lip.
5 Synthetic bonded sealing member. Its sealing lip is held against the shaft with an exact uniform pressure by the garter spring. The sealing lip should always face the lubricant being sealed.



Courtesy of C.R Industries

A lip seal can be bonded, its flexible sealing material formed and bonded onto a metal case; or it can be assembled, its parts made separately and then assembled and crimped to an outer case (Figure 6-17).

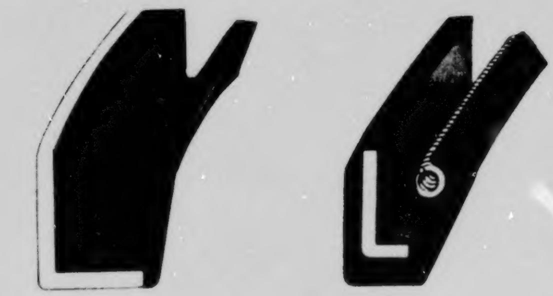


(6-17)

BONDED SEAL ASSEMBLED SEAL

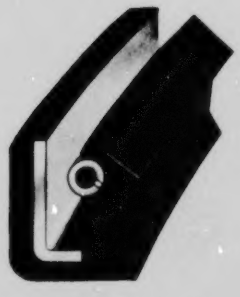
Courtesy of John Deere Ltd.

Lip seals are classed by the type of lip. Single lip not spring loaded, single lip spring loaded, and double lip are three of the most common lip types (Figure 6-18).



Ⓐ SINGLE LIP SEAL
Not Spring-Loaded

Ⓑ SINGLE LIP SEAL
Lip Spring-Loaded



Ⓒ DOUBLE LIP SEAL
One Lip Spring-Loaded

(6-18) BASIC LIP TYPES OF RADIAL LIP SEALS

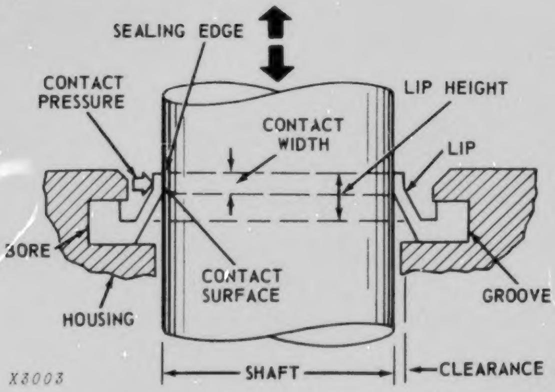
Courtesy of John Deere Ltd.

Lip Seal Operation

A radial lip seal is press fitted into a housing bore. The lip of the seal contacts the shaft thus retaining the fluid contained within and helping to prevent dirt from getting into the system. Note that complete sealing is not desired. What is wanted is a slight leakage which leaves a thin film of oil on the shaft that lubricates and helps to cool the moving parts. The tension of the lip contact is usually set by a spring in the seal. This spring tension is very important to the correct operation of the seal. Excessive tension would cause too much friction, loss of oil film, premature failure of the seal and even wear on the shaft. Insufficient tension would allow excessive leakage.

Exclusion Seals

Exclusion seals are used to exclude or prevent entry of dirt and other unwanted contaminants that would damage the moving parts. For example, an exclusion seal is needed to prevent scoring of a piston rod on a hydraulic cylinder. Figure 6-19 shows a typical radial exclusion seal.



(6-19) RADIAL EXCLUSION SEAL

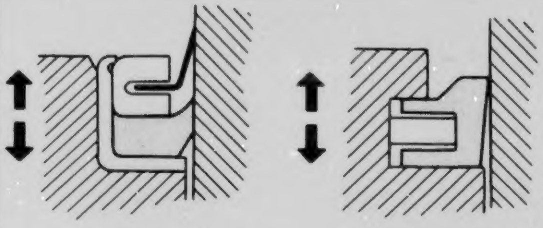
Courtesy of John Deere Ltd.

Exclusion seals are often used in conjunction with a single lip radial seal; the exclusion seal keeps out unwanted materials while the lip seal retains the fluid. The two seals are installed next to one another with the lips facing in opposite directions. These seals are not interchangeable.

Types Of Exclusion Seals

Wipers — sealing is done by a wiping action of a stationary leather or rubber lip, often on reciprocating shafts.

Scrapers — stationary metal lip scrapes heavy clinging material off reciprocating shafts (Figure 6-20).

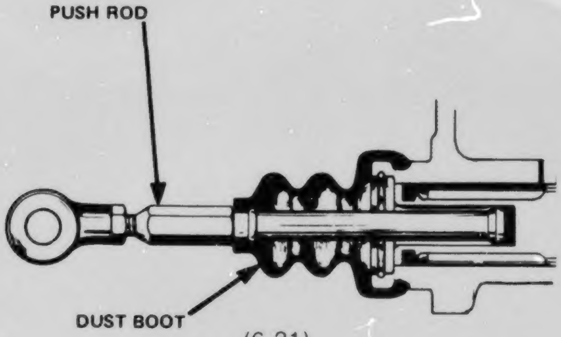


CONICAL SCRAPER RING SCRAPER

(6-20) SCRAPERS

Courtesy of John Deere Ltd.

Boots — boots differ from the above seals in that there is no actual sealing by frictional contact. A boot is a tubular flexible cover (Figure 6-21).

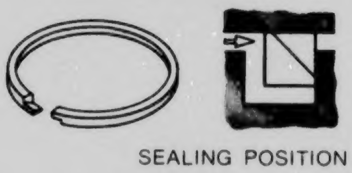


(6-21)

Courtesy of Bendix Corporation

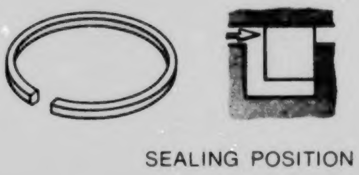
Metallic Ring Seals

Metallic ring seals are used to seal pressurized fluids or air on reciprocating parts, e.g., piston rings in an engine. They also are used to form a channel on a shaft to direct oil from a housing to a shaft, e.g., rings on a shaft in a power shift transmission. The expanding split ring design (Figure 6-22) is the most common metallic ring seal. Figure 6-23 shows ring seals on a piston.



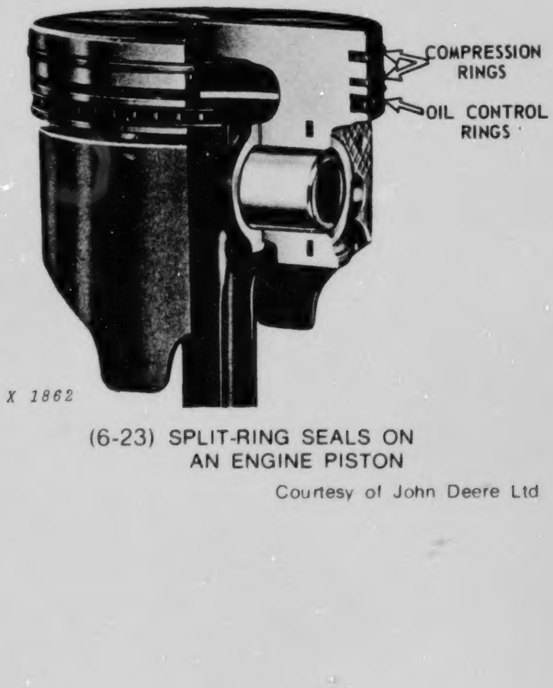
(6-22) STEP SEAL RING

Courtesy of John Deere Ltd.



(6-22) STRAIGHT-CUT SEAL RING

Courtesy of John Deere Ltd



(6-23) SPLIT-RING SEALS ON AN ENGINE PISTON

Courtesy of John Deere Ltd

A metallic ring seal in a free state is larger than the cylinder bore it will fit into. When installed in the grooves on the piston and compressed to fit the bore, the ring applies a pressure contact to the cylinder walls forming a seal.

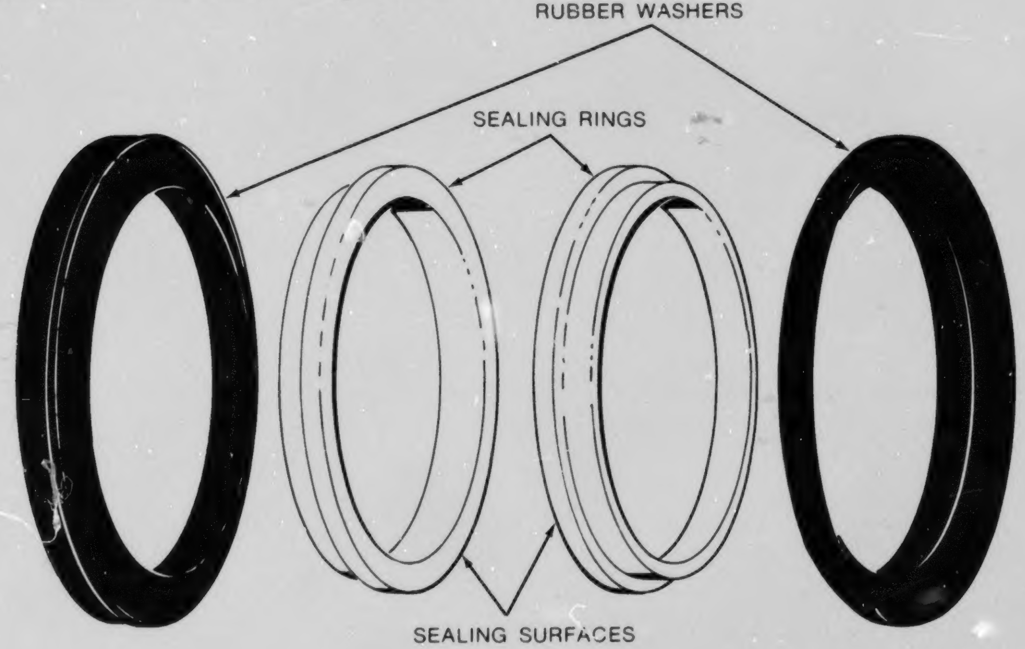
Ring seals require a thin film of oil between the outside of the seal surface and the bore it runs in to reduce friction and prevent scoring.

Note that the ends of a split ring when compressed are required to have a slight clearance to allow for expansion. The type of end joint will depend on what is being sealed and under what amount of pressure. Two types of joints are shown in Figure 6-22.

Metallic Face Seals (Floating Ring Seals)

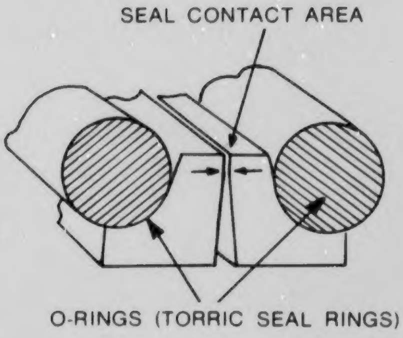
Metallic face seals (Figure 6-24) do an excellent job of sealing under severe conditions. Having exclusion as well as inclusion capabilities makes them ideal for use in heavy equipment in such places as:

Track Rollers
Idler Rollers
Front Idlers and
Final Drives



(6-24)

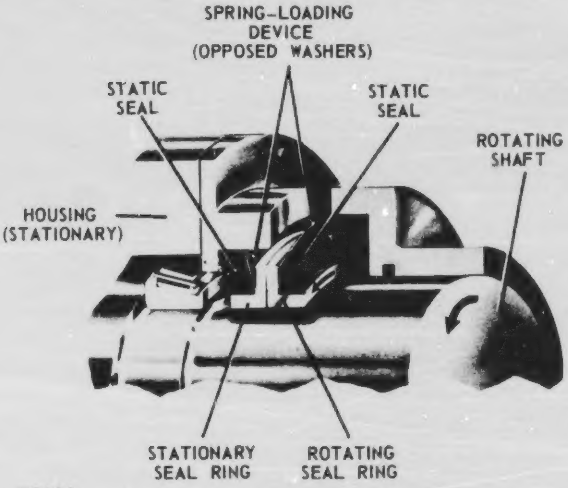
Courtesy of J.I. Case



(6-25)

The two mated seal rings of metallic face seals are precisely lapped to one another. In operation the sealing faces have a narrow contact at the outside diameter (Figure 6-25) and the remainder of the faces are tapered back slightly. As the seals wear the area of contact increases, moving across the width of the seal.

The metal sealing rings are held in contact by O-rings also referred to as torric seal rings. One metal seal ring and its O-ring is fitted into a housing bore of a stationary part, while the other seal ring and O-ring is fitted into a bore of a moving part as is shown in Figure 6-26.


SPRING-LOADING DEVICE (OPPOSED WASHERS)
STATIC SEAL
STATIC SEAL
ROTATING SHAFT
HOUSING (STATIONARY)
STATIONARY SEAL RING
ROTATING SEAL RING
X3016

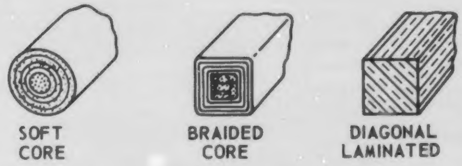
(6-26)

Courtesy of John Deere Ltd.

Compressed Packings

Placed in a stuffing box next to a moving shaft or rod, packing material is compressed to form a seal against the shaft or rod. For example, packing is used to seal rotating shafts in pumps, or to seal reciprocating shafts such as a piston or a piston rod in a hydraulic cylinder. There are two basic kinds of packing: string packing and molded ring packings ("U" or "V" types).

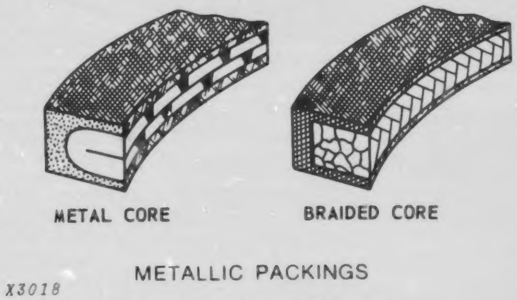
String packings are generally woven and twisted asbestos fibres or strips of soft metal formed into round, square or rectangular shapes of various thicknesses (Figure 6-27). The packing strands are treated with grease and/or graphite, or with teflon, which is becoming increasingly popular. String packings are sold in rolls and cut at the required lengths.


SOFT CORE
BRAIDED CORE
DIAGONAL LAMINATED

FABRIC PACKINGS

(6-27)

Courtesy of John Deere Ltd

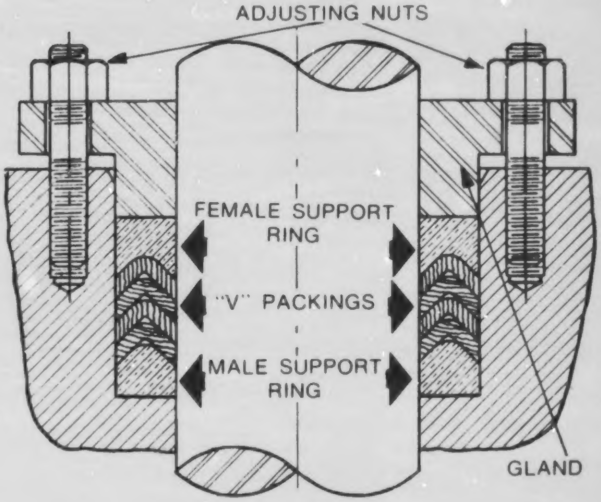

METAL CORE
BRAIDED CORE
X3018

METALLIC PACKINGS

(6-27) STRING PACKINGS

Courtesy of John Deere Ltd

Molded, compressed packings are circular rings made of various materials compressed into definit "U" or "V" cross-sectional patterns. The compressed rings come in various sizes depending on the shaft bore they are to fit. Several of these molded rings are used with metal back up rings on either side, one of which may be spring loaded. Figure 6-28 shows molded "V" packings (with back up rings) used to seal a reciprocating shaft.


ADJUSTING NUTS
FEMALE SUPPORT RING
"V" PACKINGS
MALE SUPPORT RING
GLAND

(6-28)

Compression packing is installed in a stuffing box or counter bore over the shaft it will seal and squeezed to a proper fit by an adjustable gland. This gland may be a bolted flange as in Figure 6-28 or a threaded adjuster ring. Glands require frequent adjustment to compensate for packing wear.

The size of compression packing is very important. If too small, it will require too much compression to seal. If too large, it will cause the joint to be tight and overheat. Compression packing, like other seals discussed, needs a slight film of oil between it and the shaft, otherwise it will wear rapidly.

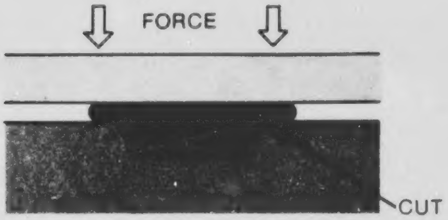
O-Rings (Dynamic Seals)

O-rings are the simplest and yet the most common of all seals. They can be used to seal revolving shafts, reciprocating piston or piston rods, or oscillating parts that move in a forward and reverse direction.

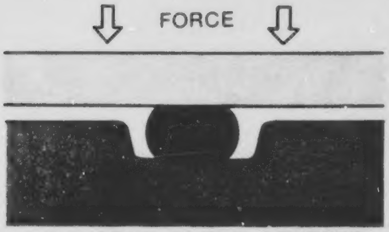
There are many types of O-rings differing mainly in their cross-sectional shapes (flat, rectangular, square, round), and in the materials they are made of. The most common ones are round and are made of a synthetic material such as neoprene which is impervious to most fluids. O-rings generally have a slash of color paint to identify operating temperature or compatibility with fluids.

O-rings are designed to fit in a groove and to be squeezed slightly. The groove is a little wider than the ring to allow it to spread out when squeezed and to move from side to side in the groove. In some places, where O-rings are under high pressure, back up rings will be used to reduce chipping of the seal.

Figure 6-29 shows the use of incorrect and correct sized O-rings with respect to squeeze and rolling action.

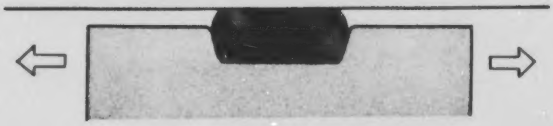


INCORRECT: TOO-LARGE RING

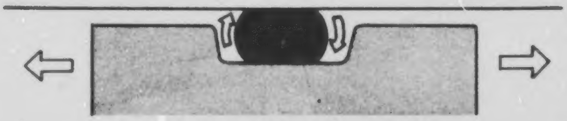


CORRECT: SLIGHT SQUEEZE

(6-29) O-RING SQUEEZE
Courtesy of John Deere Ltd



INCORRECT: NO ROLLING ACTION



CORRECT: ROLLING ACTION

(6-29) Courtesy of John Deere Ltd

STATIC SEALS

Static seals are used to seal non-moving parts. Three types of static seals are:

Gaskets — non-metallic — paper, cork asbestos, rubber and plastic.

metallic — corrugated thin metal (copper steel aluminum), metal jacketed, with soft filler (copper steel aluminum with asbestos filler).

O-Rings — rubber, neoprene, plastics (nylon, teflon) and metal.

Sealants — Hardening, non-hardening, and tapes.

Gaskets

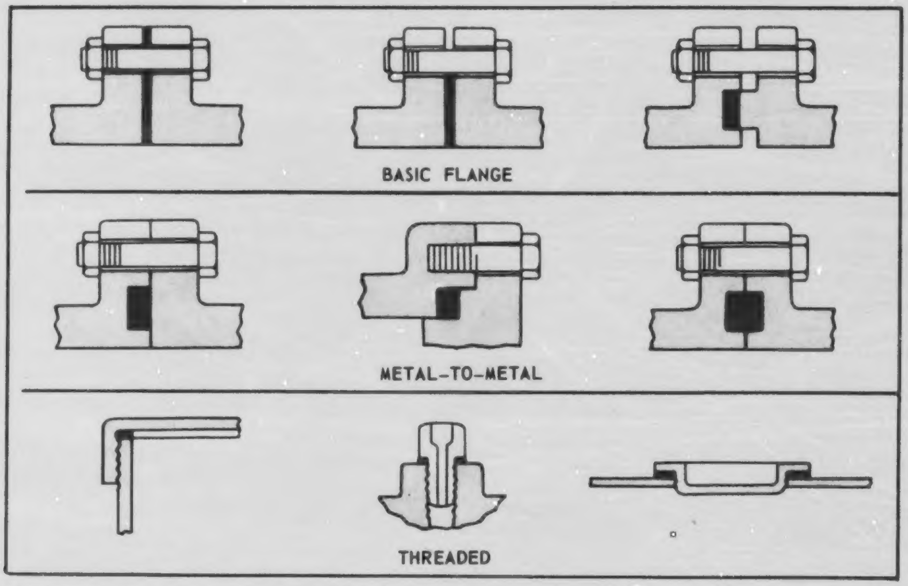
Gaskets provide a seal against the movement of fluids or gases across two mated surfaces of a housing or across the mated surfaces of a housing and a connecting container. Some gaskets are installed with sealing pastes or liquids, while others are installed dry. Figure 6-30 shows some common types of gasketed joints.

Minimum stress required depends on:

Material — cork would not require as much stress as an asbestos gasket.

Pressure — higher pressures require more stress to seal.

Fluid sealed — type and viscosity of the sealed fluids affect the required stress.

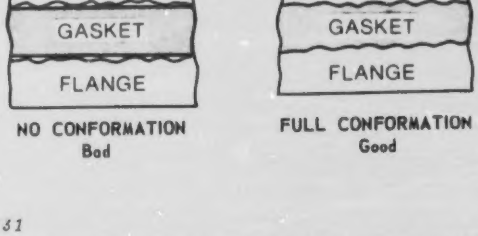


(6-30) COMMON TYPES OF GASKETED JOINTS

Courtesy of John Deere Ltd.

Flange finish — a rough flange surface requires greater stress for the gasket to conform than does a smooth flange surface would.

The joints between two stationary, mated surfaces is only as good as its gasket. Gaskets must be of suitable material to seal the surfaces and they must be installed correctly. Gasket fit refers to the term "minimum stress required", the minimum amount of stress it takes to make the gasket material conform to the irregularities of the flange faces and thus for a seal (Figure 6-31).



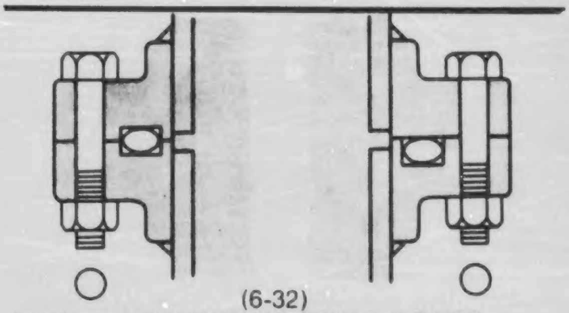
X3031

(6-31) CONFORMATION OF GASKET TO FLANGE

Courtesy of John Deere Ltd.

O-Rings (Static)

A static O-ring is a type of gasket that seals the movement of fluids across two mated surfaces. Figure 6-32 shows two static O-ring installations.



X3033

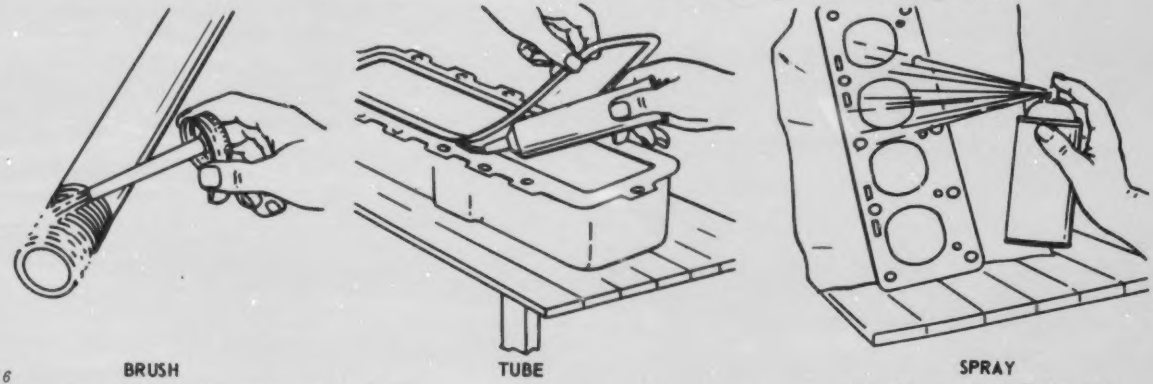
(6-32)
NON-METALLIC STATIC O-RINGS
IN FLANGE JOINTS
(TWO TYPES OF RECTANGULAR
GROOVES SHOWN)

Courtesy of John Deere Ltd.

Like dynamic O-rings, static O-rings fit in a groove and are squeezed or compressed by about 10% of their thickness. It is important to install the correct size O-ring as one too large will squeeze out between the flange, and one too small will not have sufficient tension to seal.

Sealants

Sealants perform a job similar to that done by gaskets. Where a gasket is a set shape and size though, a sealant is applied in liquid or paste form. Sealants are generally applied to a joint that has less pressure and lower temperature than a joint where a gasket would be used. Sealants are also used to provide a protective coating, to reduce noise and to aid in sealing gaskets. Sealants can be applied by brush, tube, or spray (Figure 6-33).



BRUSH TUBE SPRAY

(6-33)

Courtesy of John Deere Ltd.

Sealants may be broadly classed as:

Hardening — these may be rigid or flexible when dried.

Non-Hardening — these never really dry and are used on low stress joints more as adhesive than as sealants.

Sealing tapes are also available. They come in a variety of types, but the most common one is teflon tape. The main purpose of the tape is to seal brass or iron pipe threaded fittings. The tape is wrapped around the male thread one or two times and as the fittings are screwed together, the tape spreads between the threads to help form the seal.

GOOD PRACTICES WHEN REMOVING AND INSTALLING SEALS

1. Never install an old seal. If a seal is removed, it should be replaced wtih a new one.
2. Use only the correct seal recommended by the manufacturer. Do not substitute seals.
3. Be sure the seal, the shaft, the seal bore or groove is absolutely clean on assembly.
4. If a seal is leaking don't just replace the seal — take a quick look for the cause of the leak.

As well as normal frictional wear, possible causes could be (Figure 6-34):

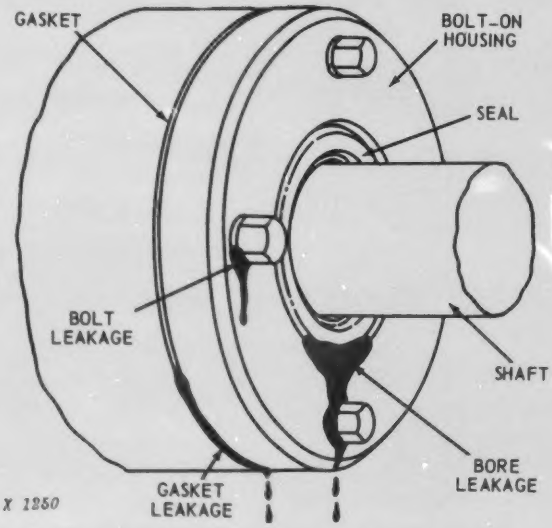
(a) worn shaft support bearings allowing excess movement of the shaft.

(b) plugged vent creating excess pressure within the housing.

(c) worn or scored shaft seal surface

(d) high temperature.

(e) what looks like a seal leak could be in fact a loose bolt, a cracked housing, or a worn gasket.



(6-34) COMMON TYPES OF OIL LEAKS

Courtesy of John Deere Ltd.

REMOVING AND INSTALLING SEALS

Following are some tips and procedures for removing and installing radial lip and exclusion seals, metal face seals, compression packing, O-rings and gaskets.

RADIAL LIP AND EXCLUSION SEALS

Removal

Remove the seal by using one of the following methods:

- — slide hammer puller with reverse jaws
- — drift and hammer
- — heel bar or pry bar.

Once the seal is removed carefully examine it for signs that may point to the cause of failure, e.g.,

seal is hardened — possible over heating.

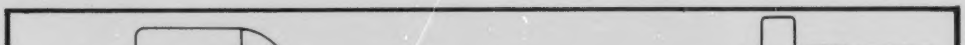
seal is soft or swollen — incompatibility of fluid with seal material.

seal lip is worn — normal fatigue, or possibly excessive shaft movement.

Installation

The installation points given for lip seals and for the other seals following are general; for specific procedures see a service manual.

1. Clean and file smooth any nicks or burrs from the housing bore and the shaft.
2. Coat the seal surface with oil or light grease.
3. If the seal has a metal case, coat its outside diameter sparingly with a light film of gasket cement.
4. Place the seal in the housing, putting the lips toward the fluid it will seal. Using a hammer and the seal installation tool (Figure 6-35) with the correct I.D. and O.D. adapters, carefully drive the seal into position. Do not strike the new seal directly with the hammer or metal tool. If the correct tools are not available, select a round ring such as an old bearing cup which fits the O.D. of the seal to drive in the seal. A square block of wood would do as well. Be sure not to drive on the inner diameter as this will damage the lip and cause early seal failure.
5. A seal can be easily damaged. When a shaft with splines or threads must be passed through a seal improvise a sleeve to protect the seal.



SOME OF THE FIXTURES USED FOR PROPERLY INSTALLING A LIP-TYPE OIL SEAL:

① AN INSTALLATION TOOL IS EMPLOYED TO PRESS FIT THE SEAL IN A HOUSING BORE PRIOR TO INSTALLING THE SHAFT. THE O.D. OF THE TOOL IS SLIGHTLY SMALLER THAN THE O.D. OF THE SEAL.

② A CONE IS USED TO PERMIT THE SEAL TO PASS OVER SHARP CORNERED SHAFT ENDS.

③ A SLEEVE WILL PROTECT THE SEALING LIP WHEN PASSING OVER KEYWAYS, SPLINES, SHARP EDGES OR ROUGH SURFACES.

④ A TOOL FOR INSTALLING AN OIL SEAL OVER A SHAFT MUST APPLY PRESSURE EVENLY AND NEAR THE OUTER PERIPHERY OF THE SEAL. SEAT SEAL WELL WITHIN THE HOUSING BORE, ALLOW FOR SHAFT AND BORE CLEARANCE IN AND AROUND THE TOOL.

(6-35) **Tools For Properly Installing Lip-Type Oil Seals**

Courtesy of John Deere Ltd.

METAL FACE SEALS
(Floating Ring Seals)

Removal

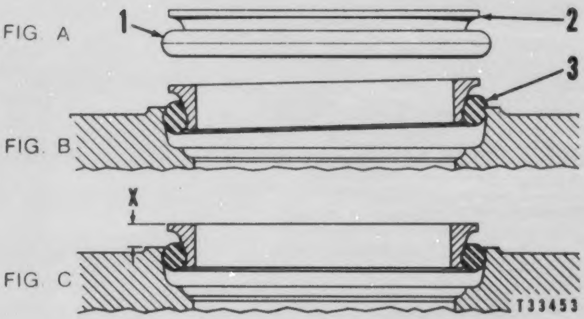
After the part using the metal face seal is disassembled, simply pull the seal halves from the housing.

Installation

1. Metal face seals are the exception to the rule that seals are not reused. Providing that the mating surfaces of the seals are not worn more than 1/3, the pair of metal face seals can be reinstalled.

   Note: Only install a pair that has run together: never install a new ring seal with a used one. Toric rings are never reused: always install new ones.

2. Clean: smooth and dry the seal support bores.
3. Ideally a metal face seal installation tool can be used. Be sure that the toric seal ring accompanying the metal face seal is installed flat and straight in the bore.
4. If an installation tool is not available use finger pressure (not a screw driver) to install the toric ring, and be sure the metal face seal is sitting level in the support bore (Figure 6-36).
5. Clean the two metal faces and coat them with a slight film of light oil.



INSTALLING FLOATING RING SEAL AND TORUS SEAL

1—Torus seal. 2—Floating ring seal. 3—Location to press on seal. X—Dimension to be checked.

(6-36)

GASKETS

Removal

Removing a gasket is a straight forward procedure. Even if a gasket is not damaged on removal, always replace it with a new one.

Installation

1. Clean all old gasket material from the housing and flange faces and clean all threaded holes. Smooth all burrs and sharp edges with a file.
2. Check for cracked bolts, for flange cracks or damage. Using a straight edge check the flange faces for warpage. Make any necessary repair or replacement.
3. If a ready made gasket is not available select the correct type and thickness of gasket material and make one.
4. On assembly carefully align the gasket with holes in the housing. It may be necessary or helpful to use an aid such as line up studs, gasket cement, or grease to hold the gasket in place.
5. Some gasket locations require a sealant to help form the seal. On the other hand, cork gaskets and metal exhaust gaskets are usually assembled dry.
6. Torque all bolts in sequence to specified pressure.

COMPRESSION PACKINGS

Removal

Remove the packing gland, the back up ring, and pry out the packings.

Installation

1. Clean the packing bore, the shaft, the gland, and back up rings with solvent and blow them dry. File or emery smooth any burr or nicks on the shaft, bore or gland. Replace worn or damaged parts.
2. When installing packing rings:
   - Lubricate liberally each ring of a new packing.
   - Install the packings with the "V" pointing toward the gland.
   - Stagger the diagonal split joints of the packing rings.

3. Cycle the unit and check the gland adjustment.
4. Don't over tighten. The gland should be tight enough to prevent leakage but loose enough to coat the shaft or rod with a thin film of oil.

O-RINGS

Removal

Removal of O-rings is a straight forward procedure.

Installation (Dynamic O-rings)

Care must be taken not to damage the O-ring on installation:

1. Clean and smooth the seal groove.
2. Select the correct size and type of seal (O-rings often have an identifying point slash). Be sure, too, that the seal is compatible with fluid it will seal.
3. Lubricate the seal with the same fluid as in the system.
4. Avoid stretching and twisting O-rings on installation. Also, protect them from sharp edges.
5. After installation, cycle the unit several times to allow the seal to find its normal position.
6. Properly installed, O-rings should pass a slight film of oil for lubricaton to prevent scuffing.

Installation (Static O-rings)

There is a little more tolerance for installing static O-rings but care still must be observed:

1. Clean the groove and flange faces.
2. Select the correct size and type of O-ring.
3. Align the parts carefully and the torque flange evenly.

QUESTIONS — SEALS

1. What are the two basic types of seals and what is each used for?
2. Name three jobs a seal may be required to do.
3. When installing a lip seal, is it desirable to have a slight leakage? Explain.
4. When installing a lip seal, which way should the lip go?
5. Which has more positive sealing action, a lip seal or a metallic face seal? Under what type of conditions are metallic face seals used?
6. Should compression packings allow a slight leakage when adjusted correctly? Explain.
7. What effect does gasket material have on minimum stress required to make the gasket conform to the irregularities of the flange faces?
8. When an O-ring is used as a static seal, how much should it compress? What would happen if an O-ring that is too large is used?
9. Bores, shafts, and flange surfaces should be _________ before installing a new seal or gasket.
10. Which is the accepted rule when an old seal is removed?
    (a) Carefully inspect it, and, if not too badly worn, reinstall it.
    (b) Replace it with a new one.
11. A ______________________ tool should be used when installing a lip seal.
12. Can metallic ring seals be reused? What about the toric or tension O-rings?

ANSWERS — SEALS

1. Static seal — seals stationary parts.

   Dynamic seal — seals moving parts.

2. Retain a fluid

   Exclude dirt

   Hold pressure

   Hold a vacuum

3. Yes, a slight leakage lubricates the moving parts and helps to cool them as well.

4. Towards the fluid it will seal.

5. A metallic face seal. Metallic face seals are used in severe conditions that require a strong, positive seal (e.g., track rollers).

6. Yes, for the same reason as lip seals: to lubricate and cool the moving part.

7. A soft material conforms easier than a harder one and therefore less stress is required to form a seal with a gasket of soft material.

8. About 10%. Too large an O-ring will squeeze out between the flange faces.

9. . . . cleaned . . .

10. (b) Replace it with a new one.

11. . . . seal installation . . .

12. Yes, metallic ring seals can be reused providing that the sealing surfaces are not more than 1/3 worn. The toric O-rings, on the other hand, should always be replaced.

TASKS — BEARINGS AND SEALS

SEALS

1. Remove front wheel seal, and install a new seal using the correct size seal driver.

ANTI-FRICTION BEARINGS

1. Using the correct type and size of pullers or pressing equipment, remove and install bearings located, for example, in a track machine final drive or in any location where bearings are installed with a press fit.
2. (a) Remove all the bearings from a front wheel assembly, clean the bearings with petroleum solvent and inspect them. Replace any bearings that are not serviceable.

   (b) Using the correct type of grease specified in the service manual, pack the front wheel bearings.

   (c) Install the bearings.

   (d) Taking a torque wrench, adjust the front wheel bearing to the preload or clearance specified by the manufacturer.

BLOCK

6

Track Machine Undercarriage

PURPOSE OF TRACK MACHINE UNDERCARRIAGE

The term undercarriage refers to the complete assembly that supports a track machine. The undercarriage of a dozer or loader includes two track frames, the components mounted on the track frames, and the tracks. The undercarriage of a shovel or excavator includes the track frame unit (called the truck frame or carbody), the components attached to the track frames, and the tracks.

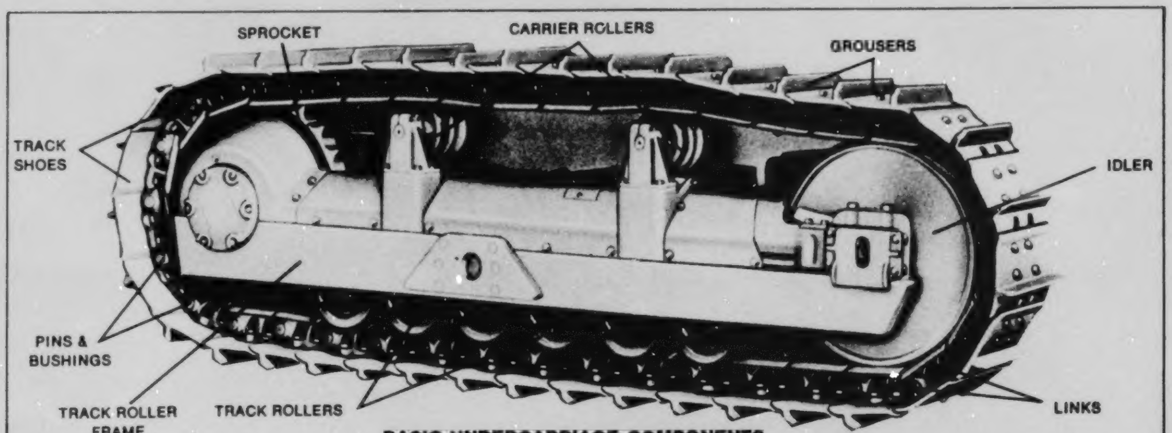
The purpose of undercarriages of crawler loaders, crawler dozers, excavators shovels or cranes is to:

— support the machine
— drive the machine
— provide ground flotation

The question might be asked, why are tracks necessary? Couldn't rubber tires do the job? The answer is no: rubber tires will not give the flotation, traction and mobility that track machines need to work in soft, rough, or uneven terrain.

CRAWLER LOADER AND CRAWLER DOZER UNDERCARRIAGES

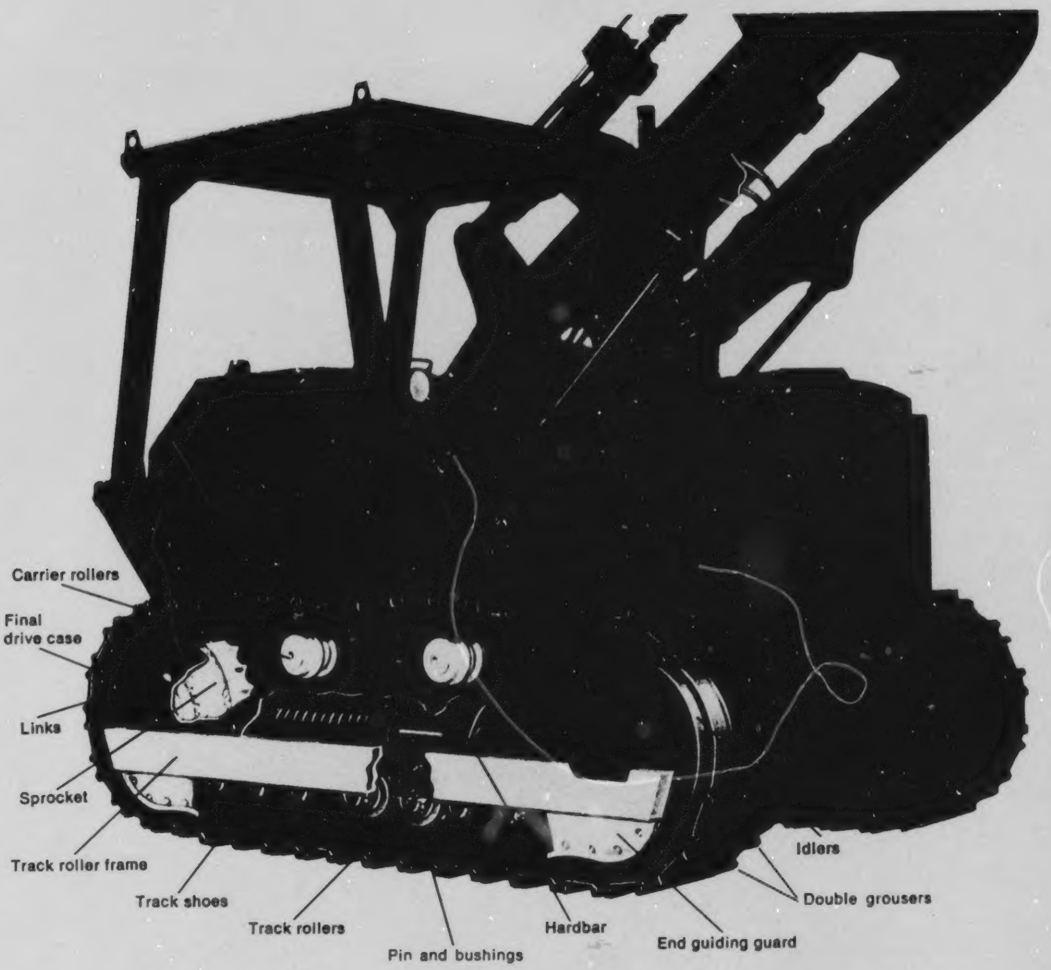
The undercarriage design for crawler dozers and loaders is virtually the same — a track chain with bolt-on shoes is driven by a sprocket located at the rear of the machine. The track follows a path over the carrier roller(s) attached to the topside of the track frame, around an idler at the front of the machine, under track rollers attached to the underside of the track frame, and finally back to the sprocket. Figure 6-37 shows a dozer undercarriage, and Figure 6-38 a loader undercarriage.



BASIC UNDERCARRIAGE COMPONENTS

(6-37)

Courtesy of Caterpillar Tractor Co.

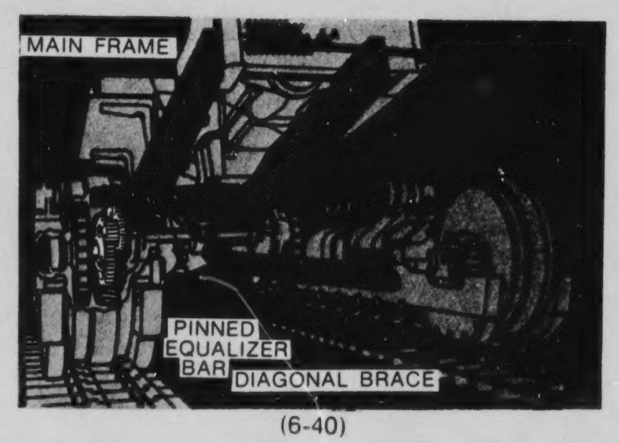

Carrier rollers
Final drive case
Links
Sprocket
Track roller frame
Track shoes
Track rollers
Pin and bushings
Hardbar
End guiding guard
Idlers
Double grousers

Courtesy of Caterpillar Tractor Co.

(6-38)

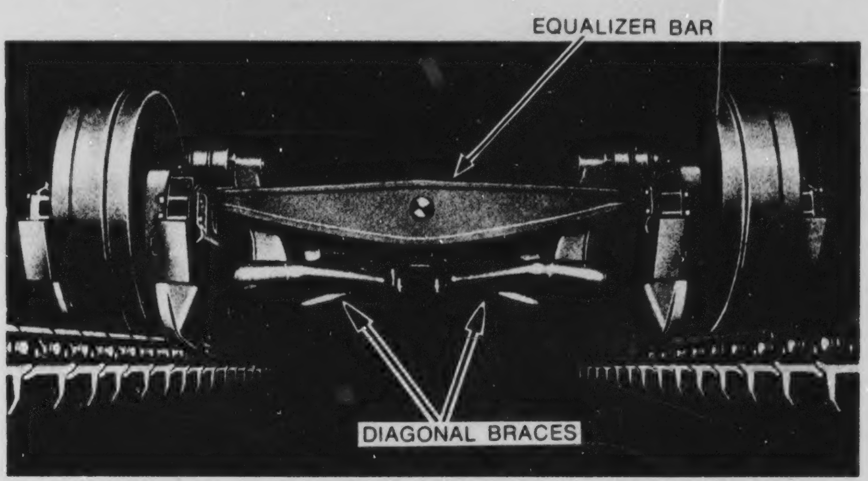
The main difference between crawler dozer and loader undercarriages is the way they are mounted. Crawler dozer undercarriages are mounted so that each track frame can move up and down independent of the other. This method of mounting permits maximum track contact with the ground when the machine is working on rough uneven terrain.

Figures 6-39 and 6-40 show dozer track frames sitting on their tracks. The frames are mounted separately on bearings at the diagonal braces. The weight of the front of the tractor rests on an equalizer bar, which in turn rests on the two track frames. The equalizer bar pivots at its center allowing each track to independently move up or down as the tractor's weight shifts while moving over rough, uneven ground.



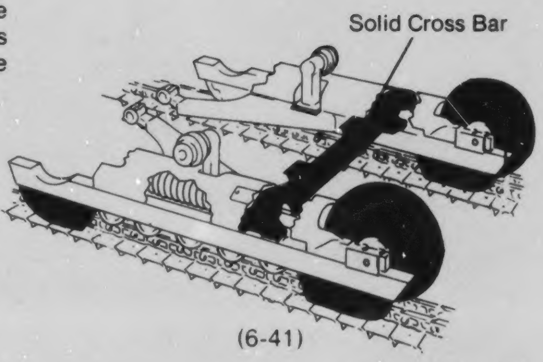
(6-40)

Courtesy of Caterpillar Tractor Co.



(6-39) Courtesy of Caterpillar Tractor Co.

Crawler loaders, unlike crawler dozers, need to be stable when operating. Thus the track frames on loaders are mounted so that there is no relative up and down movement of the frames. Rigid bars (Figure 6-41) joining the two track frames are bolted to the tractor's main frame and keep the two tracks on the same plane.



(6-41)

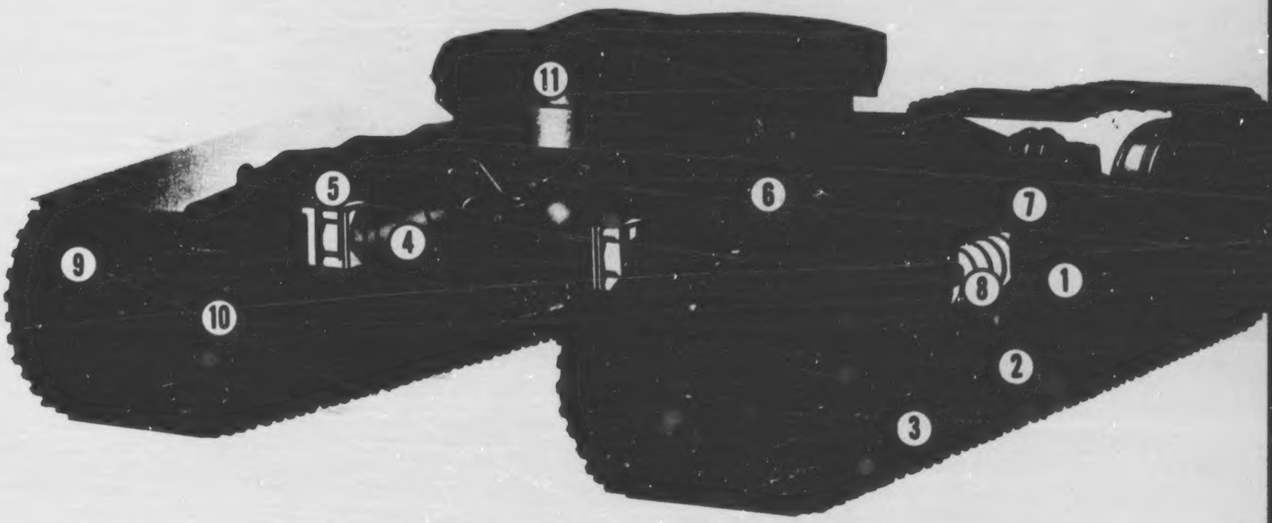
Courtesy of Caterpillar Tractor Co.

EXCAVATOR, SHOVEL AND CRANE UNDERCARRIAGES

Excavator undercarriages (Figure 6-42) are similar to those of dozer loaders, having the basic sprocket, flanged rollers, track chain and bolt-on shoes. Shovel and crane undercarriages (Figure 6-43) differ in that they have a drive tumbler or bullwheel, straight rollers, and shoes that are linked together to form the track.

Excavators, shovels and cranes have a broad, strong and rigid frame (the carbody, or truck frame) necessary to support heavy upper works which revolve 360° over the undercarriage. The propel and steering mechanisms, whether mechanical or hydraulic, are housed within the carbody. Because of their greater weight and size, excavators, shovels and cranes move more slowly than crawler loaders or dozers.

EXCAVATOR UNDERCARRIAGE

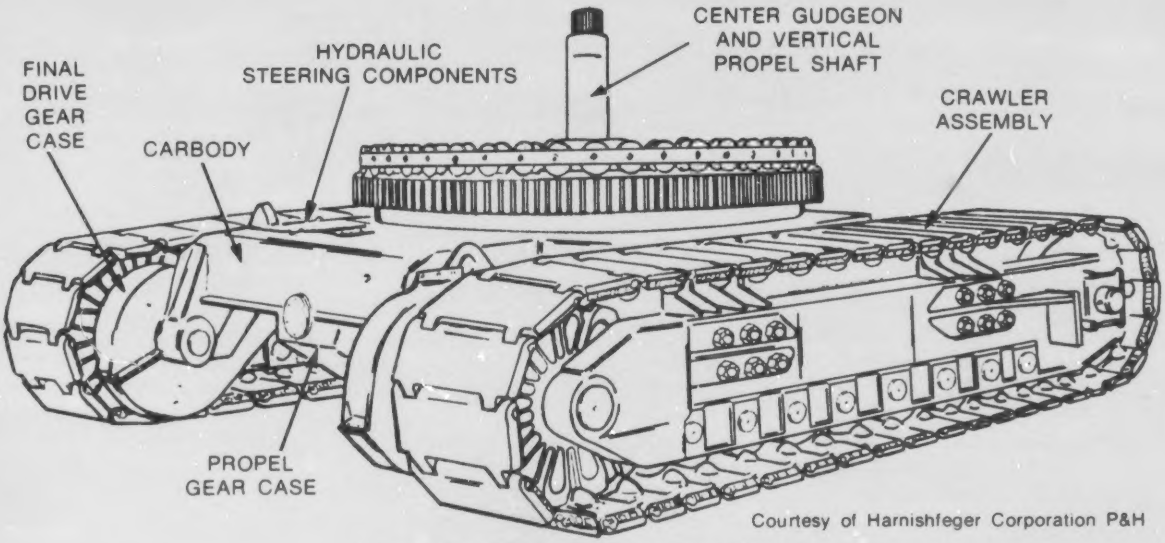


(6-42) CAT

Courtesy of Caterpillar Tractor Co.

Major components of the undercarriage are:

1. Box-beam roller frames.
2. Lifetime-lubricated rollers, carriers, and idlers.
3. Sealed track (pin-and-bushing joints).
4. Hydraulic track motors.
5. Oil disc track brakes.
6. Box-section carbody.
7. Hydraulic track adjusters.
8. Heavy-duty recoil springs.
9. Bolt-on track shoes in several widths and types.
10. Full-enclosed, triple-reduction final drives.
11. Internal swing gear.

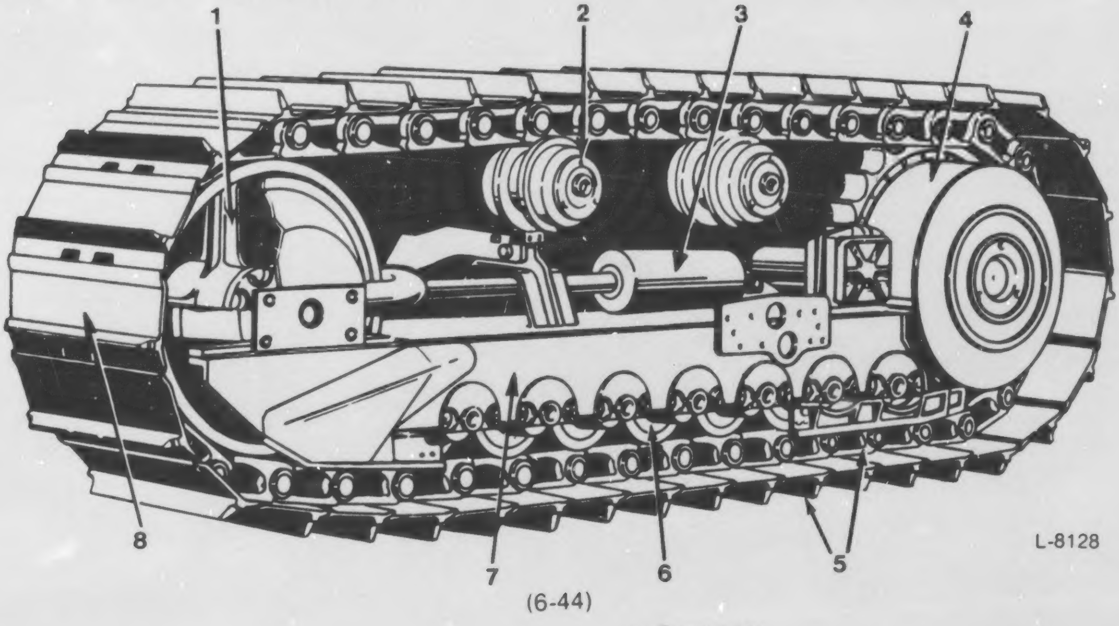

FINAL DRIVE GEAR CASE
HYDRAULIC STEERING COMPONENTS
CENTER GUDGEON AND VERTICAL PROPEL SHAFT
CRAWLER ASSEMBLY
CARBODY
PROPEL GEAR CASE

Courtesy of Harnishfeger Corporation P&H

(6-43) **SHOVEL UNDERCARRIAGE**

UNDERCARRIAGE COMPONENTS

The undercarriage components shown in Figure 6-44 are discussed below.


1
2
3
4
8
7
6
5
L-8128

(6-44)

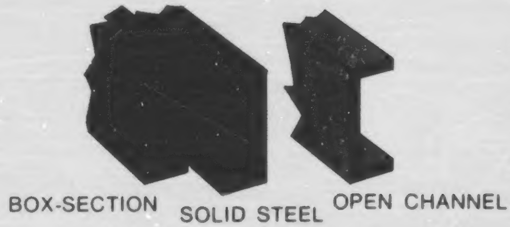
1. Front Idler
2. Carrier Roller
3. Recoil Cylinder
4. Final Drive Assembly
5. Track Chain Assembly
6. Track Roller
7. Track Roller Frame
8. Track Shoe

Courtesy of Terex General Motors Corporation

Track Frames

Track frames provide a housing onto which all the other undercarriage components are mounted. The frames are drilled and tapped or have bolting strips to mount the various components. Track frames are usually made of channel or box shaped steel (Figure 6-45). Box shaped is used on large machines as it is more resistant to cracks and bends. Solid steel is also used on some large machines.

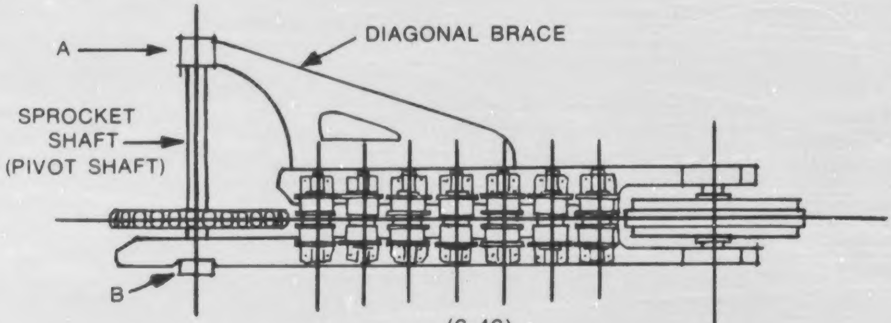
Dozers with oscillating (moving up and down) track frames require some way of keeping the frames in alignment. One way is to weld a diagonal brace to the inside face of the track frame, thus allowing the frame to be attached to the rear of the tractor at two points along the sprocket centerline, points A and B in Figure 6-46.


BOX-SECTION
SOLID STEEL
OPEN CHANNEL

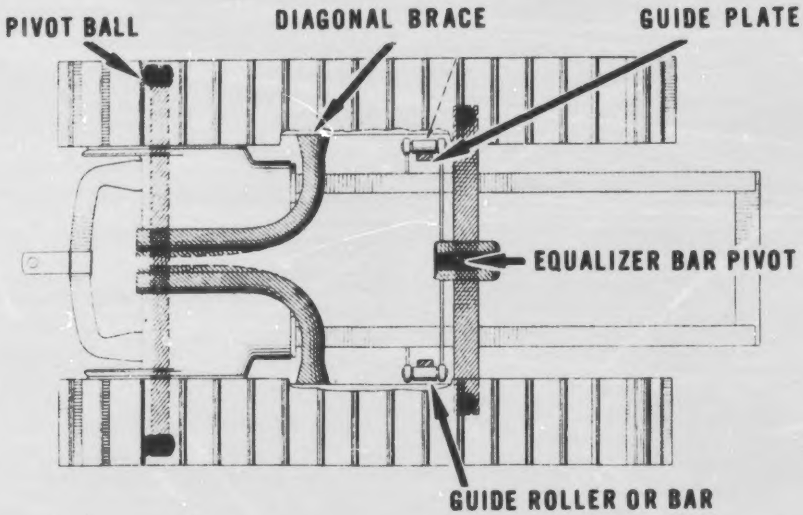
(6-45) CAT

Courtesy of Caterpillar Tractor Co.

Some manufacturers attach the frame ahead of the sprocket centerline and they may or may not use a diagonal brace. To further aid frame alignment dozers have a guide roller or bar towards the front of the machine. The guide rollers in Figure 6-47 are located just behind the equalizer bar.


DIAGONAL BRACE
A
SPROCKET SHAFT (PIVOT SHAFT)
B

(6-46)


PIVOT BALL
DIAGONAL BRACE
GUIDE PLATE
EQUALIZER BAR PIVOT
GUIDE ROLLER OR BAR

(6-47) Courtesy of International Harvester

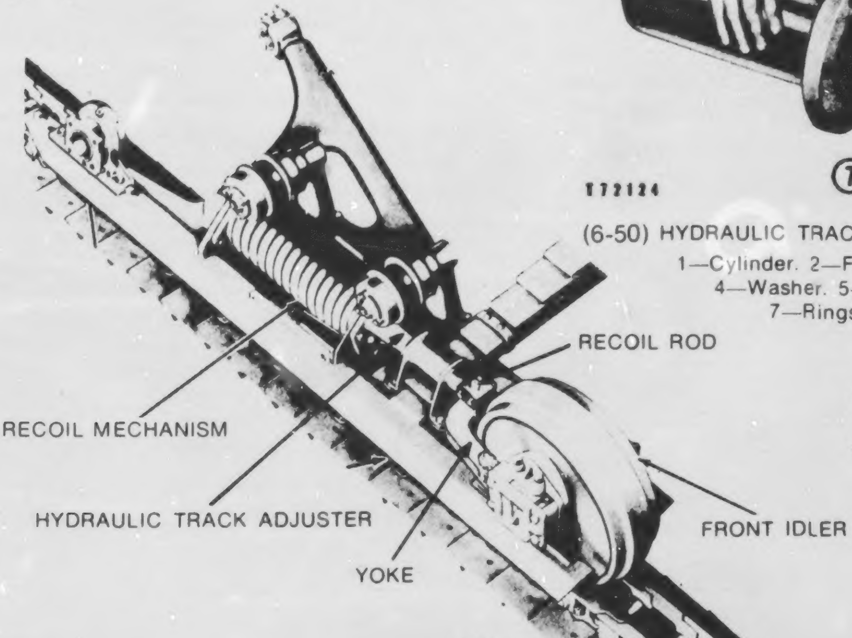
Recoil Mechanism and Hydraulic Track Adjuster

The recoil mechanism located within each track frame is either a large coil spring(s), a gas charged cylinder, or a stack of conical discs. The purpose of the recoil mechanism is to:

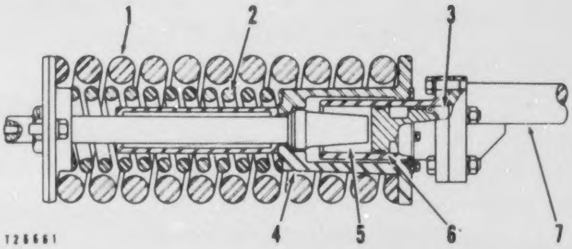
- Act as a shock absorber for forces striking the front of the track.
- Provide some give for the track if debris gets caught in the sprockets or chain links, or if material builds up in the sprocket teeth.

On machines using springs as a recoil mechanism the springs are compressed to a specific length. Then they are held by a through-bolt and positioned between stops welded or bolted to the track frame. Recoil springs on some crawlers are submersed in oil within the frame.

Integrated with the recoil mechanism is a hydraulic track adjuster, a device that tightens or slackens the tracks. Many track adjusters are located between the recoil spring and the front idler (Figure 6-48). The adjuster may be part of the recoil rod or it may be fitted into the front spring seat to act against the recoil rod. Other track adjusters are positioned within the springs (Figure 6-49).



(6-48)

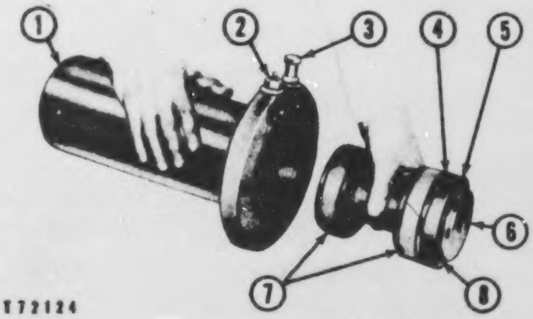


1—Spring. 2—Spring. 3—Cavity. 4—Pilot. 5—Bolt. 6—Piston. 7—Rod.

(6-49) RECOIL SPRING AND HYDRAULIC TRACK ADJUSTER

The hydraulic track adjuster (Figure 6-49) consists of a piston (6) installed in a cylinder. Grease is forced into the cavity (3) to push the recoil rod, yoke and idler outward to tighten the track. Venting the cavity will slacken the track. Figure 6-50 shows a more detailed view of a hydraulic track adjuster cylinder.

Caution: the adjuster cylinder is under high pressure. Therefore, venting the cylinder to slacken the track must be done with care.



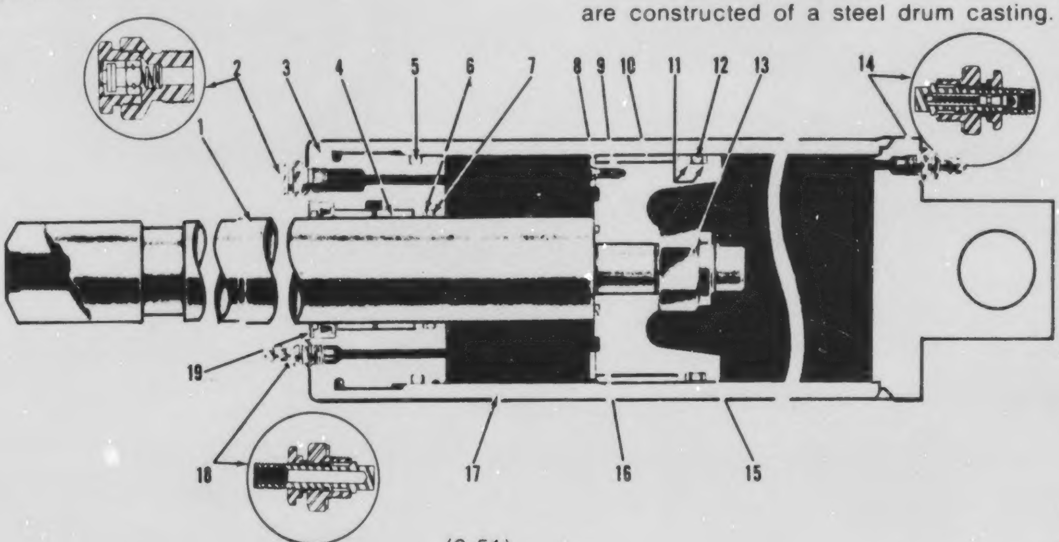
(6-50) HYDRAULIC TRACK ADJUSTER CYLINDER
1—Cylinder. 2—Fill valve. 3—Relief valve. 4—Washer. 5—Packing. 6—Piston. 7—Rings. 8—Snap ring.

Note that although most modern machines use a hydraulic track adjuster, some older or smaller machines will have a mechanical (threaded rod) track adjustment.

Some machines, Terex for instance, use a gas charged recoil mechanism and hydraulic track adjuster combined (Figure 6-51). This system works opposite to the hydraulic adjuster in Figure 6-49. Grease is added to a cavity to slacken the track and exhausted to tighten the track.

Front Idler

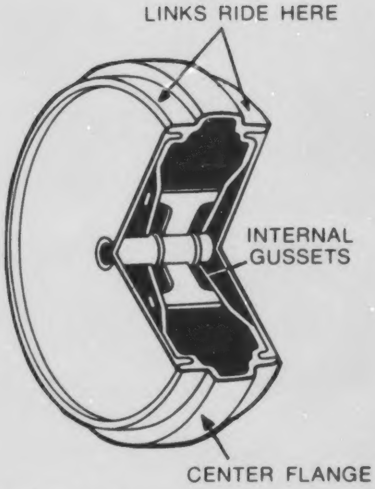
The front idler (Figure 6-52) is a large wheel attached to the front of the track frame. Idlers are mounted on bushings or anti-friction bearings, sealed (on most modern machines) by metallic face seals, and permanently lubricated on assembly. The idler both supports the track and guides it into position for the track rollers. The links of the track chain ride on induction hardened surfaces on the outer circumference of the idler. Most idlers are constructed of a steel drum casting.



(6-51)

1. Piston Rod
2. Giant Grease Fitting
3. Rod Guide
4. Bearing
5. "O" Ring
6. Backup Ring
7. "O" Ring
8. Retainer Plate
9. Screw
10. Bushing
11. Backup Rings
12. "O" Ring
13. Nut
14. Charging Valve
15. Piston
16. "O" Ring
17. Cylinder
18. Bleed Valve
19. Seal

Courtesy of Terex General Motors Corporation



(6-52) FRONT IDLER

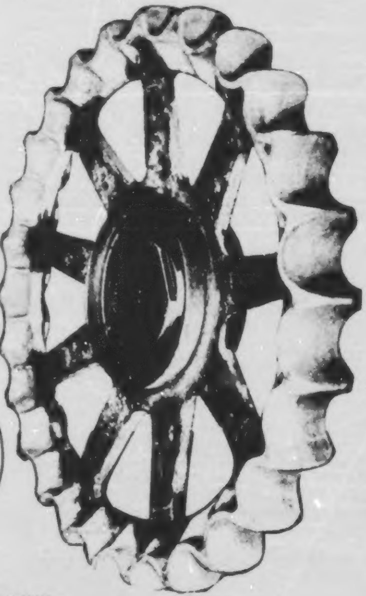
Some tractors have idlers which can be adjusted to provide either a high or low position (Figure 6-52). When the idlers are in high position there is less track-to-ground contact area, and the tractor is more maneuverable. Turning is easier there is less wear on the tracks. With the idlers in low position there is a greater length of track contacting the ground and greater stability when the tractor is equipped with heavy, front-mounted equipment. The drawback of the low position is that the increased ground contact causes more strain in turning and therefore more wear on the tracks.

The general rule-of-thumb for idler adjustment has been high position for drawbar work and low position for bulldozer work or for use with heavy front mounted equipment. However a better rule would be, that for maximum track service life idlers should be adjusted to the high position except where the low position is necessary for machine stability.

Sprockets

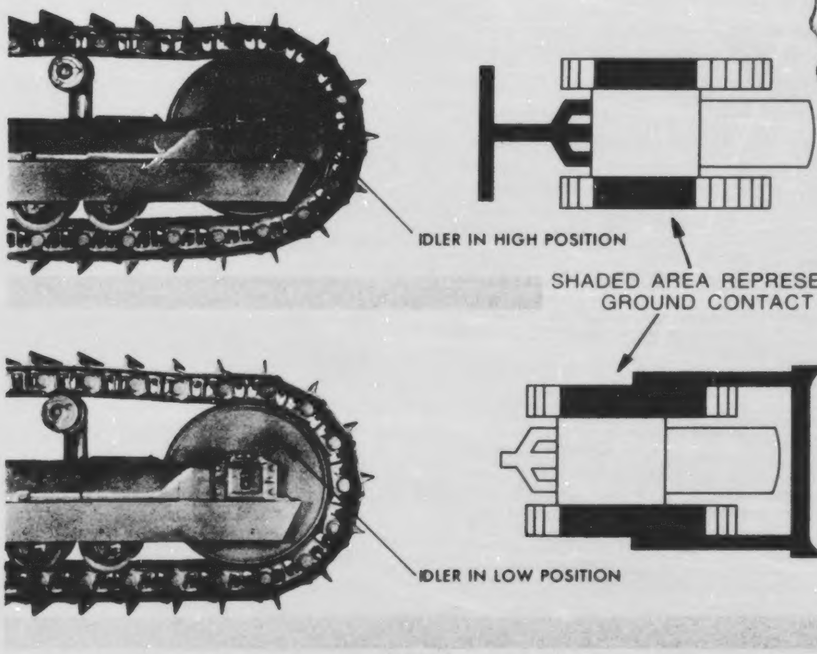
Sprockets are a large toothed wheel (of approximately the same O.D. as the front idler) located at the rear of the track frame. Attached to the final drive unit, the sprocket drives the track chain by using the bushings in the chain as leverage points.

Sprockets are made of forged or cast steel, heat treated and tempered for long life. Sprocket teeth are machined to close tolerances in a pattern called the hunting tooth design. The hunting design has an odd number of teeth spaced in such a way that each tooth contacts a chain bushing only once in two revolutions, thus essentially doubling the life of the sprocket. Four common sprocket designs are shown in Figure 6-53.



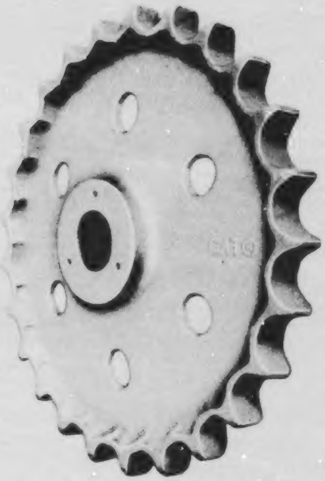
(6-53)
SPOKE SPROCKET

Courtesy of Caterpillar Tractor Co.

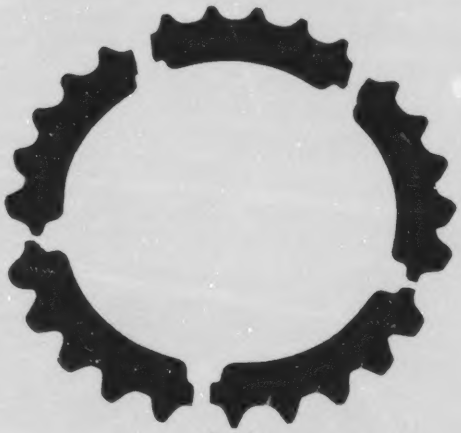


(6-52)

Courtesy of Caterpillar Tractor Co.

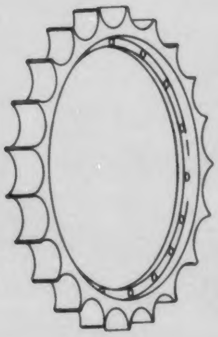


(6-53) DISC SPROCKET



(6-53)
SEGMENTED OR BOLT-ON SPROCKET

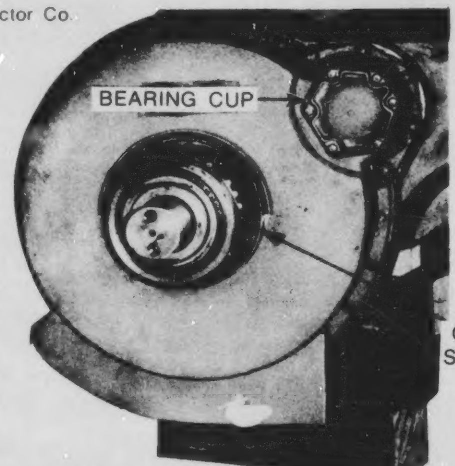
Courtesy of Caterpillar Tractor Co.



(6-53) RING SPROCKET

Courtesy of Terex.
General Motors Corporation

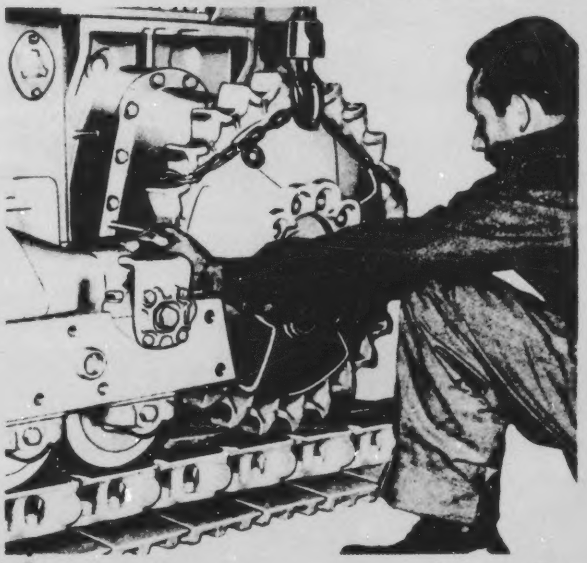
Spoke sprockets were generally used on older machines although a few are still found on modern machines. The spoke design has given way to the drive disc and bolt-on segments which are easier, and thus cheaper, to replace when worn. Disc sprockets are usually found on smaller dozers and loaders and on most excavators. Ring sprockets are another common sprocket usually found on larger machines. A ring sprocket is often used in conjunction with a planetary reduction gear assembly. Drive tumblers are used on shovels and cranes. Having no track chain, the backs of shovel and crane track shoes are shaped to accept the lug of the tumbler as a leverage point.



(6-54) Courtesy of Internation Harvester

Sprockets are mounted in different ways. One of the most common methods is to have a large tapered spline on the sprocket fitting onto a matching spline extending from the final drive (Figure 6-54). The sprocket is press-fit and retained by a large nut. A portable hydraulic press is needed to remove and to replace the sprocket.

Two other methods of mounting sprockets are (1) the sprocket or sprocket segments are bolted to a drive disc which is splined to the final drive gear, and (2) the sprocket is bolted to a final drive flange (Figure 6-55).



(6-55)

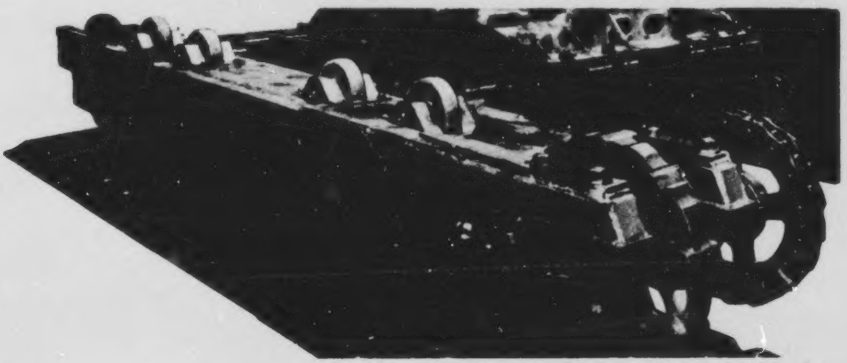
Courtesy of Massey-Ferguson Inc

Drive Sprockets and Tumblers

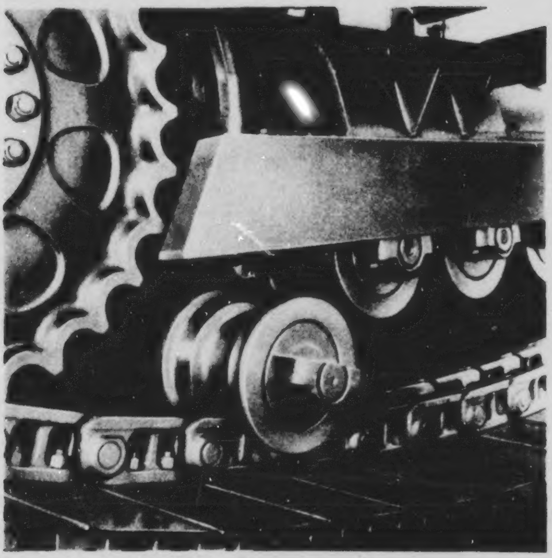
In place of a final drive and sprocket assembly many shovels and cranes have drive sprockets, chains and drive tumblers (Figure 6-56). From the drive sprocket, power is transmitted by a chain to another sprocket at the drive end of the machine. This second sprocket is connected to a drive tumbler which drives the track. The drive chain runs in the open and requires regular lubrication, and adjustment to compensate for wear.

Track Rollers

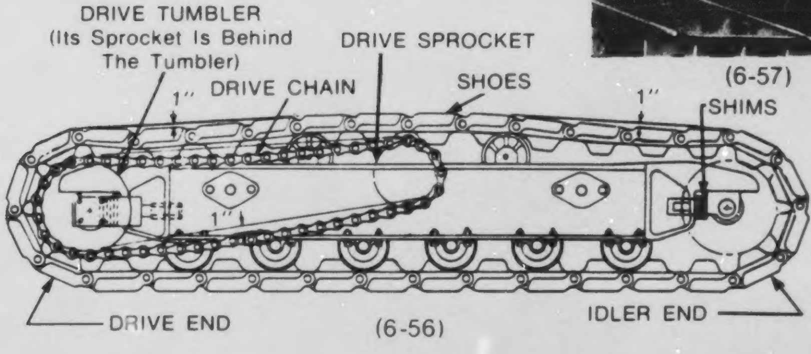
Mounted to the bottom of the track frame by end brackets, the track rollers support the machine and distribute its weight to the track chain. The rollers run on the chain links. Figure 6-57 shows a track roller dropped to the chain links. To take this picture, the track has been slackened and the track frame jacked up.



(6-56) Courtesy of Bucyrus-Erie Co.

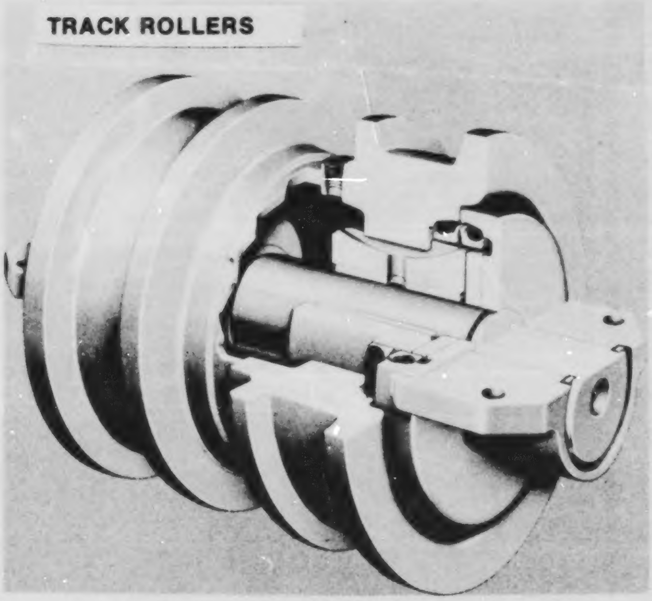


(6-57) Courtesy of Massey Ferguson Inc.


DRIVE TUMBLER
(Its Sprocket Is Behind The Tumbler)
DRIVE SPROCKET
SHOES
1"
DRIVE CHAIN
1"
SHIMS
1"
DRIVE END
IDLER END

(6-56)

Flanges aid in keeping the track on the rollers and thus in line. If the roller has outer flanges only, it is called a single flanged roller; if it has both outer and inner flanges, it is called a double flanged roller. Figure 6-58 shows a double flanged roller.



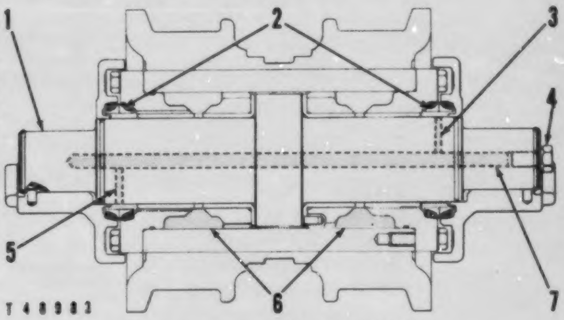
(6-58)
Courtesy of Caterpillar Tractor Co

Crawler dozers, loaders, and excavators usually have an equal number of rollers, starting with a double at the front of the machine and ending with a single at the sprocket. If there is any variation in this pattern it will occur at the front of the machine because a single flange roller always comes next to the sprocket. The number and size of track rollers will vary from machine to machine.

Track rollers for dozers, loaders and excavators have a forged steel shell with replaceable anti-friction bearings or bushings. Most manufacturers favor the bushing because it has greater load carrying capacity, is cheaper, and takes less space. The rollers turn on a stationary shaft held by end caps bolted to the track frame.

Rollers are sealed and lubricated on assembly. Most manufacturers use a metal face seal (floating ring seal), one pair on each side of the roller, because it's the most durable type of seal for the severe conditions under which rollers perform. The shaft is drilled lengthwise part way, and then cross drilled (Figure 6-59). Oil is forced into this passage and into a cavity between the roller shell and the bearings. With the roller in a horizontal position the oil is fed in with a special nozzle screwed into the end of the shaft. As the oil enters, the vented nozzle allows air to escape. Once filled to a point where oil comes out the nozzle, a plug is inserted into the shaft to seal it. The oil filled passage and cavity act as a reservoir for the roller.

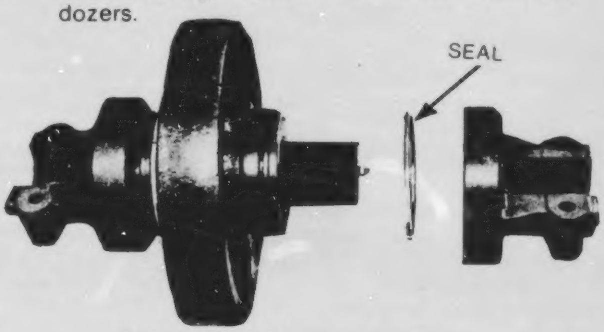
Such a lubricated roller is referred to as lifetime lubricated, although it can be topped up if required. Generally though, if a roller is leaking, trouble is indicated and the roller should be removed and repaired. Individual rollers can be removed without having to take off the track frame, as is shown in Figure 6-57).



TRACK ROLLER LUBRICATION
1–Shaft. 2–Metal floating ring seals. 3–Passage. 4–Plug. 5–Oil passage. 6–Reservoirs. 7–Passage.

(6-59)
Courtesy of Caterpillar Tractor Company

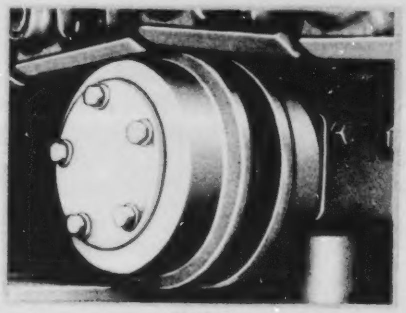
Shovels and cranes generally use a different type of track roller. It has a solid center flange which runs in a groove in the track (Figure 6-60). However, if a shovel or crane is equipped with tractor-type tracks, it will use single and double flange rollers like those used on dozers.



(6-60) SHOVEL TRACK ROLLER
Courtesy of Bucyrus Erie Co.

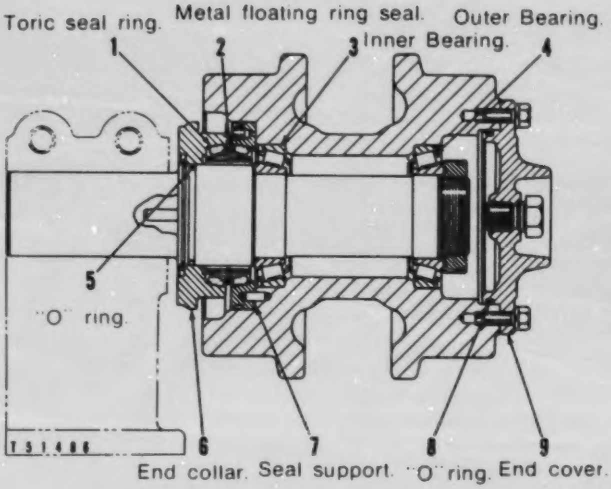
Carrier Rollers

The carrier rollers (Figure 6-61) support the upper portion of the track between the sprocket and the front idler. Carriers are mounted to the top of the track frame with a cantilever-type support bracket. There may be one or two carrier rollers depending on the size of the machine. Carrier rollers are made of a forged steel shell similar to that of track rollers, but have only a center flange.



(6-61)

Courtesy of Caterpillar Tractor Co.



(6-61) CARRIER ROLLER CROSS-SECTION

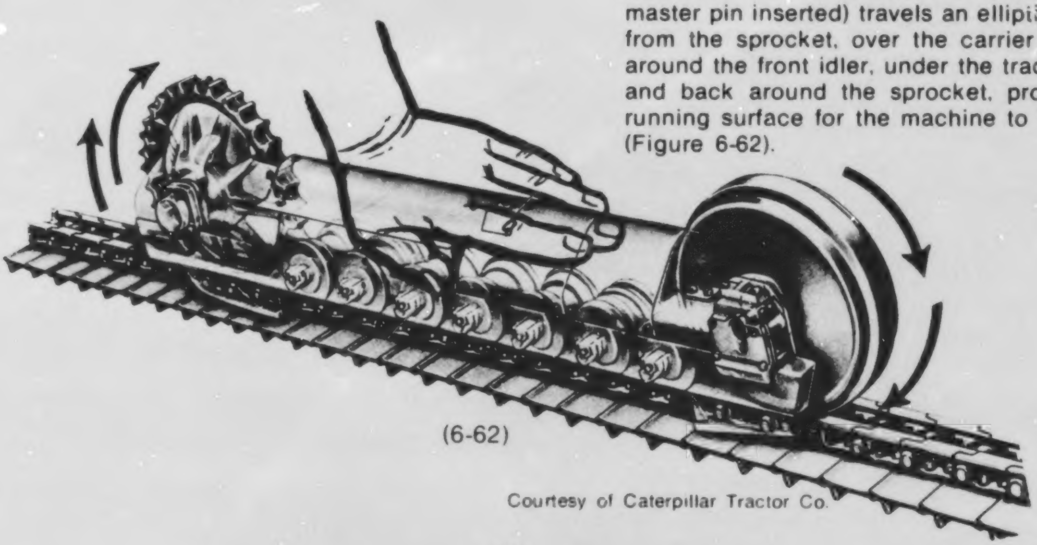
Courtesy of Caterpillar Tractor Co.

The roller is mounted on two tapered roller bearings, pressed on the stationary shaft and adjusted for preload by a nut on the end of the shaft. A pair of metal face seals is used on one end of the roller, while the other end is sealed by a cover bolted to the roller shell. Removing this plate gives access to the adjusting nut.

Similar to track rollers, carrier rollers are lubricated on assembly with a vented nozzle. Carriers, too, are referred to as lifetime lubricated.

TRACKS

Tractor tracks are made of a chain with shoes bolted to it. The continuous chain (with the master pin inserted) travels an elliptical route from the sprocket, over the carrier roller(s), around the front idler, under the track rollers and back around the sprocket, providing a running surface for the machine to travel on (Figure 6-62).



(6-62)

Courtesy of Caterpillar Tractor Co.

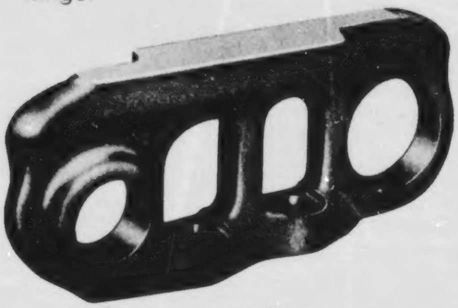
Track Chains

Track chains for a crawler dozer, loader and excavator are virtually the same, differing mainly in their size. A track chain consists of two rows of links joined together by pins and bushings. The pins and bushings have a clearance fit with one another, but are press-fit into the links (Figure 6-62).

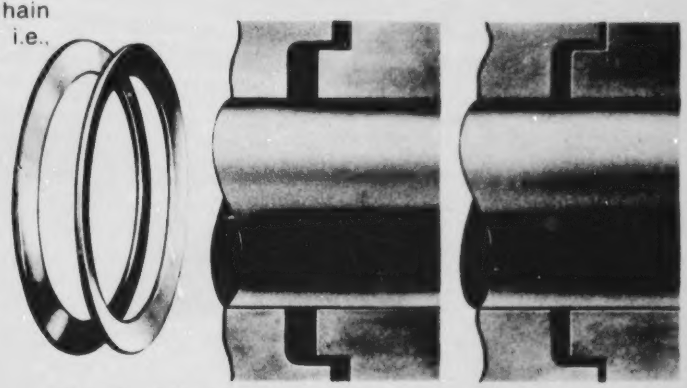
The links are drilled on the top surface to accept the shoe and are flat on the bottom to provide a running surface for the track rollers. The links are paired left and right and interlock with one another. One end of the link has a large hole to fit the bushing (with pin inside) and the other end has both a counter bore to fit the bushing and seals, and a smaller hole to accept the part of the pin extending beyond the bushing. Since the pins and bushings are slightly oversized in relation to the link bores, they must be press-fit into the bores. This press-fit both holds the chain together and allows it to be flexible, i.e., hinge.

Track chain seals are two conical washers installed back to back in the link counter bore. The seals are compressed, one against the link counter bore, the other against the bushing end, as shown in Figure 6-63. When the chain bends, the two seal washers turn against one another forming a seal.

The track chain just described is called a sealed track and is common among many manufacturers. The latest development in tracks from the Caterpillar Tractor Company is the sealed and lubricated track.



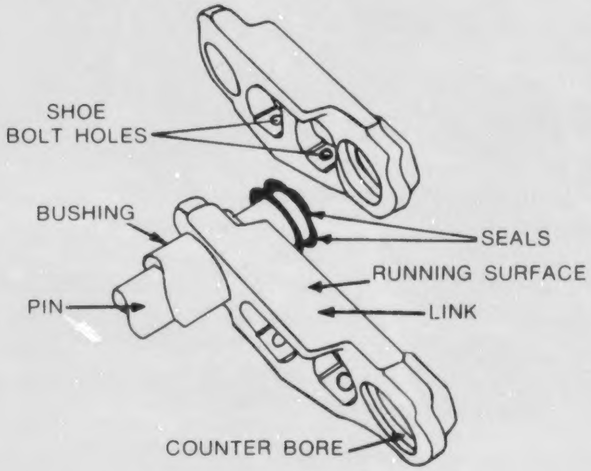
(6-62) TRACK CHAIN LINK
Courtesy of Caterpillar Tractor Co



SEALS SEALS NOT COMPRESSED SEALS COMPRESSED

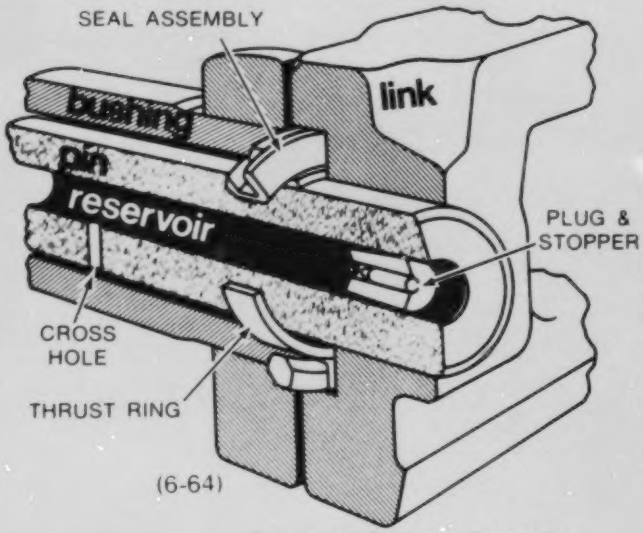
(6-63)

Courtesy of Caterpillar Tractor Co



(6-62) SEALED TRACK CHAIN

The sealed and lubricated track (Figure 6-64) uses the same link-pin-bushing arrangement as the sealed track, but the pins are lubricated and the seals are more positive (i.e., they give a more complete sealing action).



(6-64)

Courtesy of Caterpillar Tractor Co.

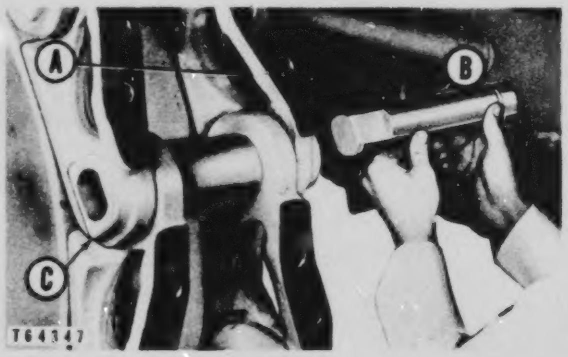
The pin is the same size and length as before but harder for added strength needed because of the hole drilled through its center. This hole is the oil reservoir. A cross hole provides a passage for oil to gravity feed to the pin and bushing contact area. After the seals are installed in the counter bore the lubricant (90EP) is added and the passage plugged with an expandable stopper. This rubber material at the end of the pin is a visual indicator of lubricated tracks.

The bushing is shorter than that of the sealed track to allow room for the wider seal. The ends of the bushing are lapped (smooth) for the seal to ride against. A two stepped bushing is used on larger machines, thicker in the center to give added strength.

Track chains, in general, are made to lengths that fit specific machines. Chains will also vary in the size of the link and in the pitch length, the distance pin center to pin center. Pitch lengths will depend on the pitch of the sprocket that drives the chain.

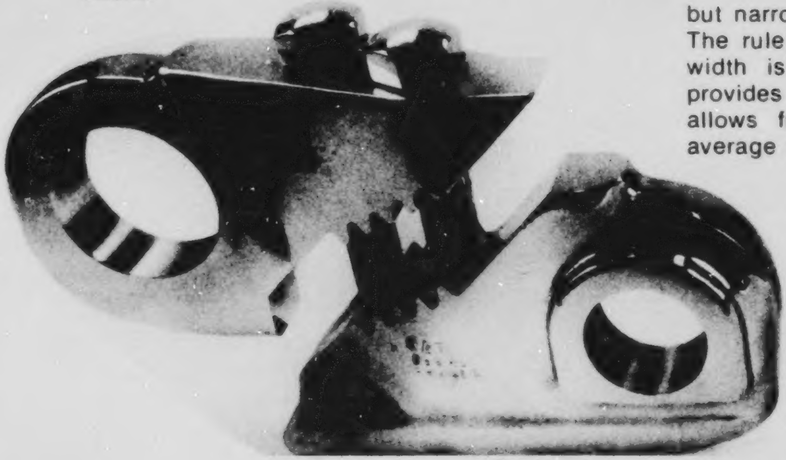
Tracks need to be coupled and uncoupled. A master pin is the most common method of separating tracks. The master pin is slightly smaller than the other pins and can easily be identified by the way it is retained, e.g., a snap ring, lock pin or machined step on one side of the pin. The master bushing, too, differs from the other bushings in that it is shorter to permit joining the track.

Figure 6-65 shows a master pin being installed. Note on this particular pin the machined flat and the matching hole in the master link.



(6-65) INSTALLING MASTER PIN
(Track Shoes Removed for Better Illustration)
A—Link. B—Master pin. C—Master link.
Courtesy of Caterpillar Tractor Co.

Large Caterpillar machines are now using a master link (Figure 6-66) in place of a master pin. This master link simplifies removal and installation in that the link has only to be unbolted to be disconnected. The link saves time, and thus money, needed to service the tracks.



(6-66) * Rc54*

Courtesy of Caterpillar Tractor Co.

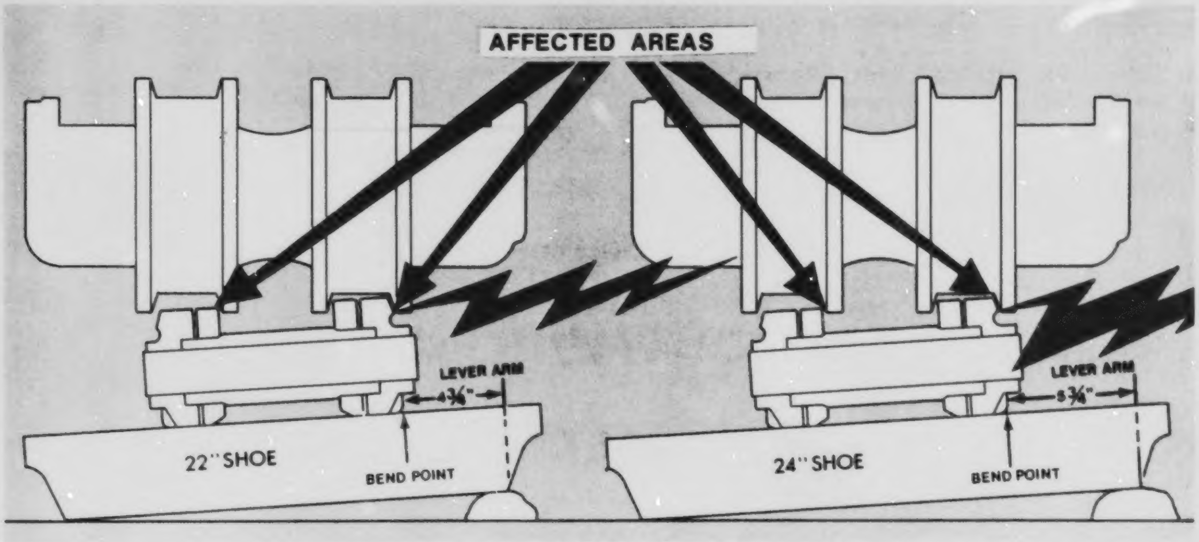
Track Shoes

Track shoes are bolted to the track chain. The shoes distribute the machine's weight over the broad surface area where the shoes contact the ground. There are many different types of track shoes, each suited to a particular machine, job and terrain.

It is important that a crawler machine have the right shoes for the job to assure maximum track shoe life and minimum wear on the other components. Terrain is probably the most important factor in selecting track shoes. Three broad terrain conditions are dirt, rock, and ice or snow. A dozer will work on everything from flat, soft soil to steep rocky slopes. A loader, on the other hand, will generally work on level compact material. Excavators and cranes work in much the same conditions as loaders, but they require a different type of shoe. The excavator shoe is broad and flat (traction is not a main concern) to give the heavy machine good stability and flotation because the upper works revolve 360°. Other factors to consider in selecting the correct shoe are:

Flotation
Traction
Penetration
Contact area (width of shoe)
Bending resistance
Self-cleaning action
Wear

Most machines have a standard shoe width, but narrower and wider shoes are available. The rule of thumb to follow regarding shoe width is to use the narrowest shoe that provides flotation and, at the same time, allows full penetration of the grouser in average conditions. The width of the shoe is critical because the wider the shoe the greater the load on the other undercarriage components. This point is illustrated in Figure 6-67: two different sized shoes walk over a rock on the outside of the shoes. The longer shoe has a greater lever arm, and therefore greater force is imposed on its roller flange.


AFFECTED AREAS
LEVER ARM
4 3/16"
22" SHOE
BEND POINT
LEVER ARM
5 3/16"
24" SHOE
BEND POINT

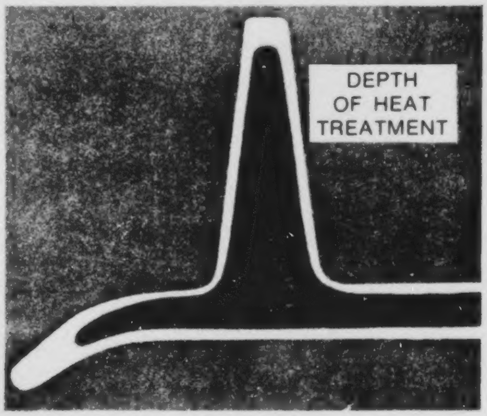
(6-67) Courtesy of Terex. General Motors Corporation

Track shoes can be grouped into two categories:

1. Grouser shoes (dozers, loaders, excavators)
2. Flat shoes (cranes, shovels)

Grouser Shoes

Grouser shoes are a flat steel plate with one or more vertical bars (grousers) that vary in height and width. The purpose of the grouser is to penetrate the ground to give traction and mobility. Figure 6-68 illustrates the heat treatment in a single grouser shoe. The light area is very hard while the darker area is softer. The soft area is necessary to allow the shoe to flex to prevent it from cracking.


DEPTH
OF HEAT
TREATMENT

(6-68)

Courtesy of Caterpillar Tractor Co.

Types Of Grouser Shoes

Standard Grouser

The most widely used all-purpose shoe on the market. Usually installed on machines as original equipment.

Center Punched Shoe

Similar in design and heat treatment to standard shoes.

Center of plate is cut out to prevent packing of snow (or mud) in sprockets.

Manganese (Current Tractor Style)

A severe duty shoe for use where shoes are subjected to severe pounding and abrasive rock.

Made of manganese steel which work hardens to about Rockwell "C" 50. The harder the shoe is used, the harder it gets.

Offset

Bolt holes offset right or left so that the tracks ride inside the scraper or dozer blade cut reducing twisting and wear of undercarriage components (Figure 6-70.

Used to advantage on all scraper push-loading and bulldozer applications on larger tractors.

Exceptionally wide offset shoes are available on a made-to-order basis for use where extreme flotation is needed.

Double Or Triple Grouser Shoes Are Generally Used On Loaders And Excavators

Double Grouser

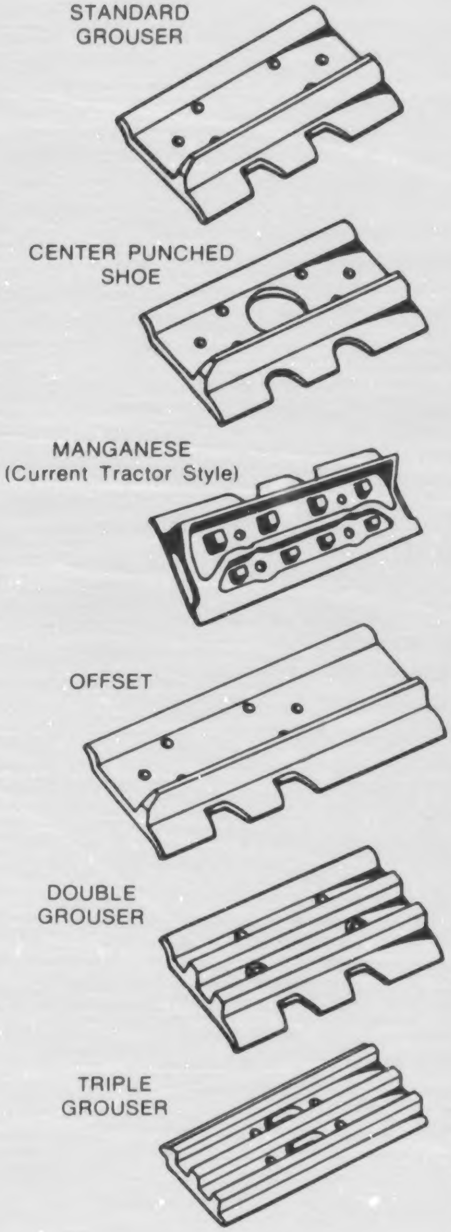
Two low grousers for less grouser wear, less turning resistance and greater manoeuverability.

Double grousers increase beam strength making the shoe less vulnerable to breaking and bending.

Greater penetration than flat shoe for better traction in occasional dirt work.

Triple Grouser

Low grousers reduce penetration, reduce turning resistance, result in a high degree of manoeuverability with minimum strain to undercarriage components.

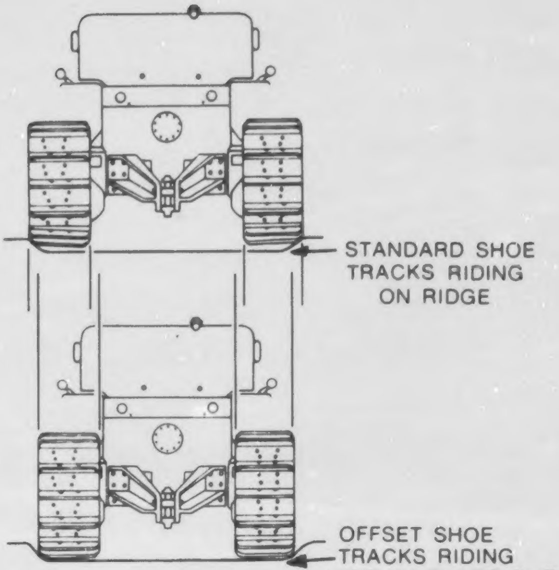


(6-69)

Three grousers for beam strength, less chance of breaking or bending, particularly on hard surfaces.

Center punched for self-cleaning in muddy conditions.

An excellent all around shoe for common soil as well as hard, smooth surfaces.


STANDARD SHOE TRACKS RIDING ON RIDGE
OFFSET SHOE TRACKS RIDING WITHIN BLADE CUT

(6-70)

Courtesy of Caterpillar Tractor Co

Flat Shoes (For Dozers, Loaders, and Excavators)

Flat shoes are a flat steel plate with no vertical bars. They are made in various thicknesses (i.e., strengths). Support, not traction, is the prime function of flat shoes. The use of flat shoes is limited, generally confined to conditions where minimum ground disturbance is required and traction is not necessary.

Flat Shoe

Flat grouserless design has great resistance to wear.

Extra thick plate is built to withstand bending or breaking.

Flat design offers no penetration and thus has least turning resistance of any of the rock shoes.

Steel Mill Flat Shoe

Similar to standard flat shoe except that notches for detachable grousers have been eliminated to prevent snagging.

Stronger than notched flat shoe. Resists breaking.

Designed for use in mills and industrial application on flat surfaces.

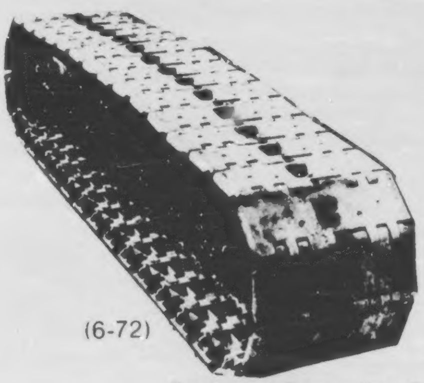
Flat design for low penetration and high manoeuverability.

Extra thick plate withstands the roughest industrial abuse.

Besides grouser and flat shoes, a third kind of shoe, a skeleton shoe with various detachable fixtures, is also used on dozers, loaders and excavators. This shoe is mainly for severe ice or snow conditions.

SHOVEL AND CRANE TRACKS

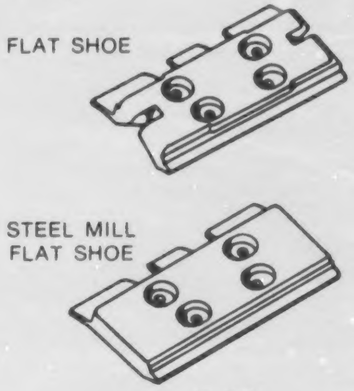
Shovels and cranes use a very different kind of track than crawler dozers and loaders. Shovels don't have shoes bolted to a track chain. Their track assembly consists of a number of identical shoes pinned together, as seen in Figure 6-72.



(6-72)

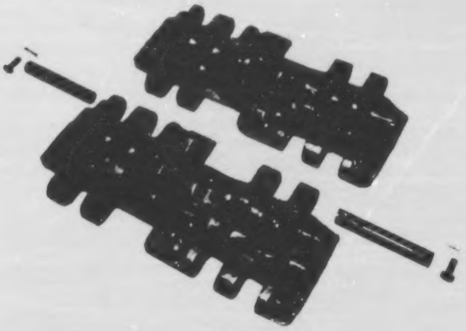
Courtesy of Bucyrus-Erie Co.

The track is driven by a drive tumbler whose teeth fit into grooves in the backs of the shoes, using these grooves as leverage points.



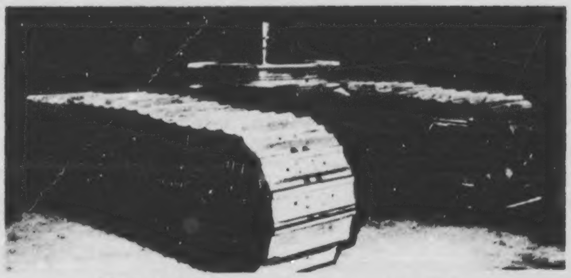
(6-71)

Shovel and crane regular track shoes are flat because these machines usually work on level ground and don't require much traction. The shoes gain their strength through thickness. Shovel and crane shoes can bend, crack or break when subjected to severe service. Figure 6-73 shows two shovel track pads and pins.



(6-73)
Courtesy of Bucyrus-Erie Co.

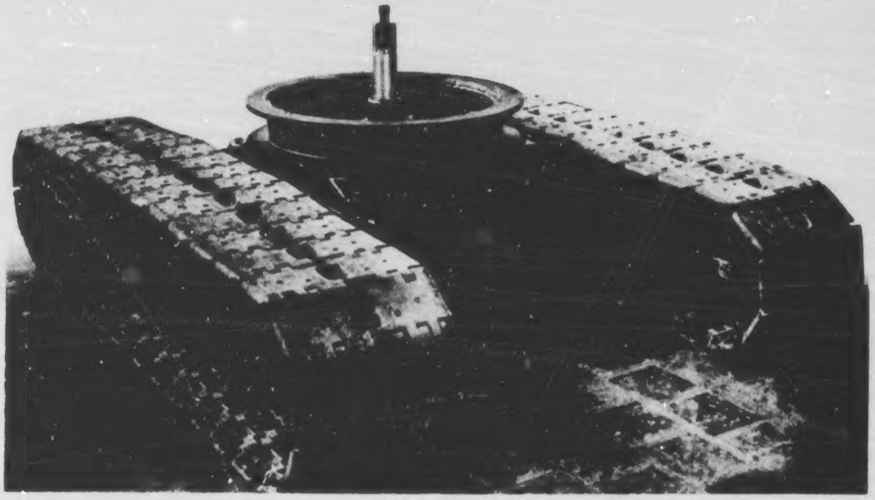
In addition to the standard shovel track, a "tractor type" track (Figure 6-74) is also available. This tractor shoe would be used on a machine such as a log loader which requires better traction than the flat shoe would give.



(6-74) "TRACTOR TYPE" TRACKS
Courtesy of Bucyrus-Erie Co.

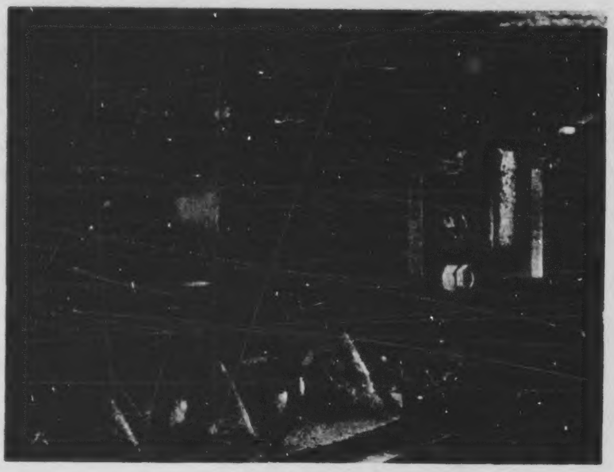
SHOVEL AND CRANE SWING ASSEMBLY

There are two methods used to support the heavy upper works, the machinery deck, of a shovel or crane and allow it to revolve 360°. One method is to place a series of rollers, referred to as house rollers, between the upper deck and the truck frame on a circular roller path. Figure 6-75 gives a view of the roller circle on the truck frame. Note the large swing gear inside the circle.

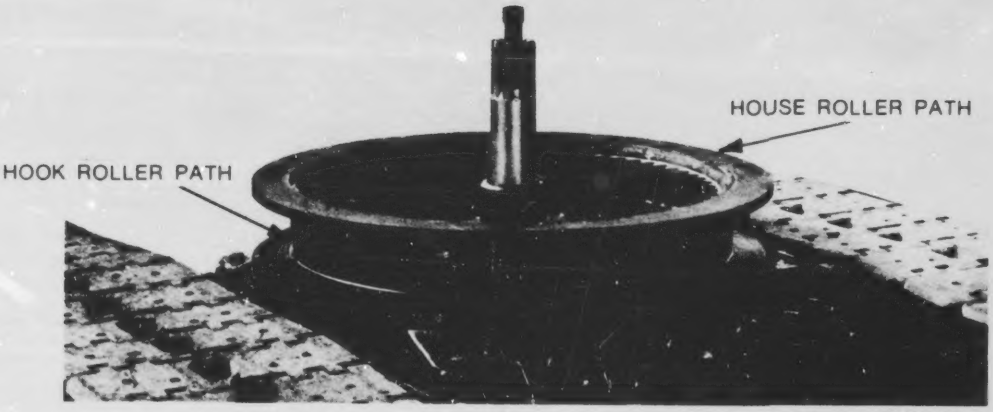


(6-75) Courtesy of Bucyrus-Erie Co.

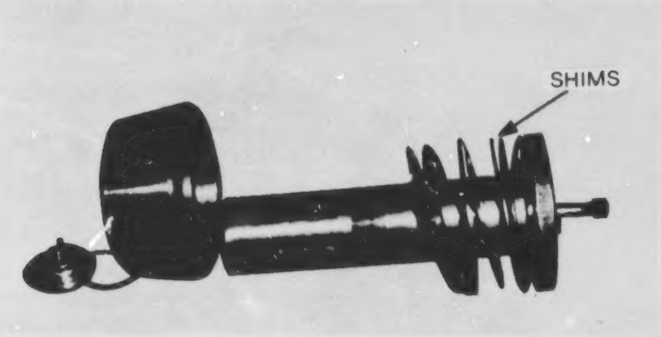
In addition to the house rollers, hook rollers (Figure 6-76) are used to hold the upper works in line and to prevent wear on the vertical swing shaft and bushings. Hook rollers are a tapered roller supported by brackets attached to the upper deck. As shown in figure 6-77, they run in a tapered groove in the swing circle just under the house roller path. Hook rollers are adjustable to compensate for wear. Note the adjusting shims on the hook roller in Figure 6-78.



(6-76) Courtesy of Bucyrus-Erie Co.

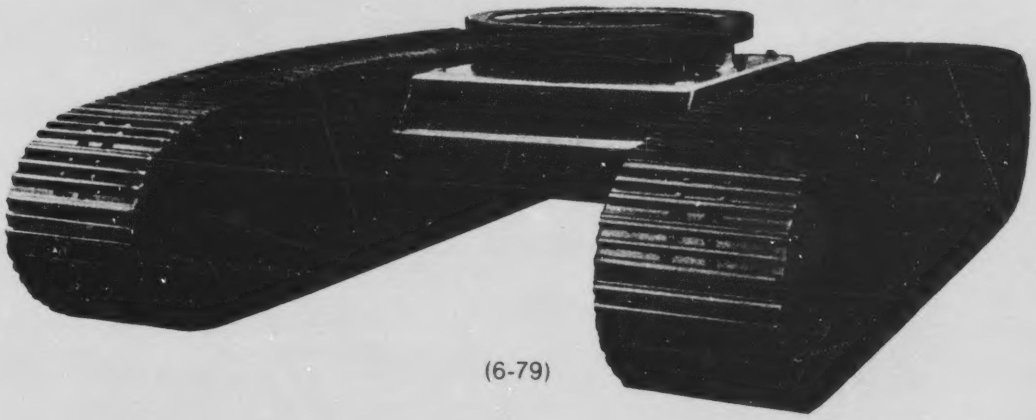


(6-77) Courtesy of Bucyrus-Erie Co.



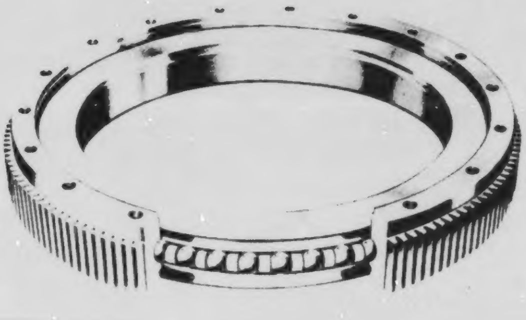
(6-78) Courtesy of Bucyrus-Erie Co.

The other method used for support and swing is a ball bearing circle. Many hydraulic excavators use this system. The ball bearing circle employs a large precision fit, anti-friction bearing in place of house and hook rollers. The outer race is bolted to the upper deck and the inner race is attached to the swing gear. Figure 6-79 shows an excavator truck frame with a ball bearing swing. Figures 6-80 and 6-81 give a closer view of the ball bearing circle.



(6-79)

Courtesy of Bucyrus-Erie Co.



Large diameter swing circles are fully enclosed anti-friction ball bearings. They are sealed to exclude dust and other foreign material.

(6-80)

Courtesy of Bucyrus-Erie Co.

(6-81)

Courtesy of Bucyrus-Erie Co.

UNDERCARRIAGE GUIDES AND GUARDS

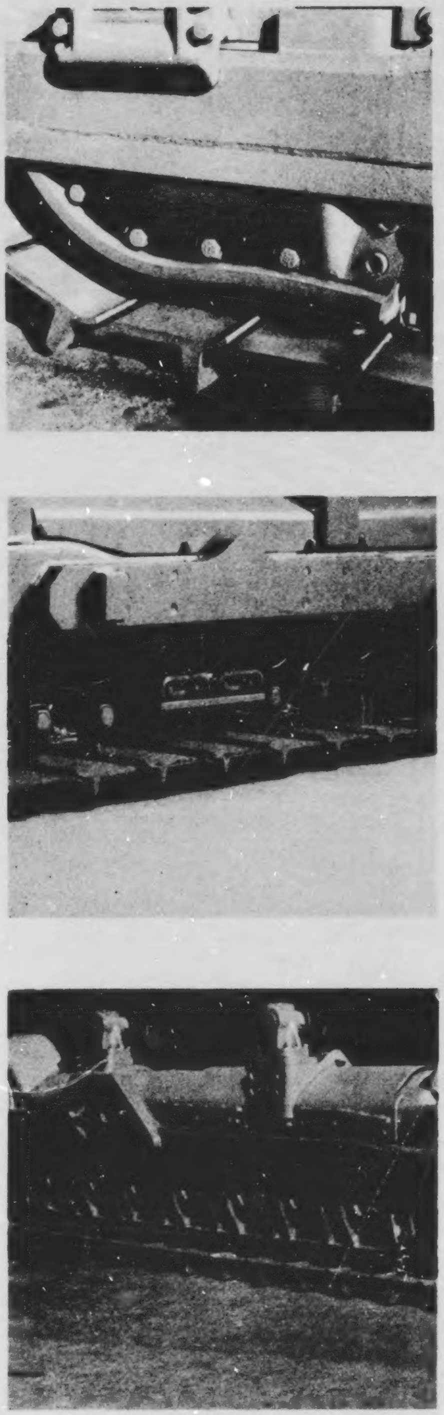
Track guides and guards (Figure 6-82) generally apply to crawler dozers and loaders.

End Track Guiding Guards assure track alignment and extended life by preventing track jumping the sprockets or scuffing the rollers during turns and severe sidehill work. They are attached to the track frame at the front and rear.

Center Track Guiding Guards help keep tracks aligned on rollers and prevent track jumping. Guards allow mud and snow to fall free of the undercarriage, reducing packing effect.

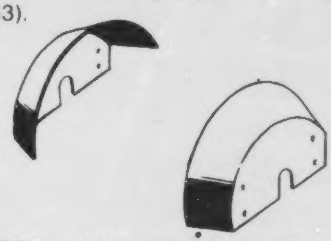
Track Roller Guards extend undercarriage life by helping keep rock away from the rollers, pins and bushings. They also help keep the track aligned, reducing undercarriage wear. The guards bolt on each track roller frame inside and out.

Guards are also available to protect the sprocket from large debris and sometimes even the idler will be equipped with a guard (Figure 6-83).



(6-82)

Courtesy of Caterpillar Tractor Co.



(6-83) TYPICAL SPROCKET OR IDLER GUARD

Courtesy of Terex, General Motors Corporation

QUESTIONS — TRACK MACHINE UNDERCARRIAGES

1. On a crawler dozer or loader the term undercarriage refers to three main groups of parts. What are they?
2. Briefly explain the main difference between a crawler dozer and a crawler loader undercarriage.
3. What is the purpose of the track frame?
4. List two methods used to keep track frames aligned.
5. Where is the recoil mechanism located on the track frame? Briefly explain its purpose.
6. Where is the track adjuster located? What are three common types of track adjusters?
7. What is the best rule to follow regarding idler position (high or low)?
8. What is the purpose of sprockets? List four common types.
9. Where are the track rollers located and what is their purpose? Explain briefly the term single and double flanged.
10. Why do track rollers generally use bushing or plain bearings rather than anti-friction bearings?
11. Where are the carrier or idler rollers mounted and what is their purpose?
12. Explain the difference between a crawler track and a crawler shovel track.
13. What does the term pitch length refer to on a track chain?
14. Give two methods used to couple or uncouple dozer or loader tracks.
15. What is the main difference between a dozer track shoe and a shovel track shoe?
16. What type of track shoe is generally found on a hydraulic excavator.
17. Why is width important in a shoe?
18. Briefly explain the location of house and hook rollers on shovels and cranes. How does this system differ from the system used on most current excavators?
19. What is the function of track roller guards?

UNDERCARRIAGE MAINTENANCE AND REPAIR

MAINTENANCE AND SERVICE LIFE

When a machine is purchased, it is thought to have a certain life expectancy. The main factor that will determine if the machine reaches its life expectancy, or goes beyond it, is maintenance. For one thing is clear: if a machine receives no maintenance, it will be in the scrapyard long before its projected life span is up.

Inspite of its importance, maintenance is often overlooked both by mechanics and machine owners. Maintenance is often neglected by mechanics because it is held in low regard. Maintenance, the thinking goes, is dull, ordinary stuff; it lacks the glamour of troubleshooting a failure, an ability that is supposed to set the average mechanic apart from the expert. Yet, if you think about it, what maintenance really is is troubleshooting a machine before the trouble has actually occurred, surely a job as demanding and complicated as trouble shooting a failure. Good maintenance practices take a lot of thought and planning, besides regularity in carrying them out.

Good maintenance is more than doing the kinds of things that mechanics have been conditioned to think of as maintenance, such as changing oil, changing filters, greasing. In general, these areas are maintained fairly well, and are rarely the cause of shortening a machine's life span. What is more likely to be the cause is a worn belt, a busted hose, a neglected leak, an ignored worn part — the simple little things that no one thinks are important. Take the lower rad hose, for example. Many would think it a pretty insignificant part of the engine, not worth much attention in comparison, say, to some parts of the fuel system. But consider what happens if these two parts fail: if the fuel part fails the engine stops or won't start. If the lower rad hose fails, in 30 seconds you've got a burned out engine, a worthless block of iron. Now which is more important?

This manual attempts, wherever possible, to point out these "little" maintenance checks that are so important to the service life of machines. The checks are usually given in the Daily, Routine Maintenance sections.

From the owners point of view, maintenance is often neglected for other considerations. On one hand, they may have the best intentions of keeping their machines well maintained, but on the other hand, they want to keep the machine working and earning money. These two desires are often in conflict, and it's frequently maintenance that takes second place as it's hard to work on a truck when it's rolling down the highway. The two main questions that owners must ask in deciding on how much maintenance to have done are:

1. How long do they want the machine to last?
2. How reliable do they want the machine to be?

It is a proven fact that service life and reliability are directly related to the care and frequency of maintenance.

DAILY ROUTINE MAINTENANCE CHECKS ON UNDERCARRIAGES

Although the undercarriage accounts for only about 20% of the purchase price of a track machine, it accounts for about 50% of the total maintenance cost of the machine. Since the undercarriage takes such a large proportion of total maintenance cost, many owners stress care and preventive maintenance of their machine's undercarriages. At the same time, though, it should be pointed out that other owners, for various reasons, run their undercarriages to destruction and then outfit the track frames with completely new components. One case where an undercarriage may be run to destruction is on a machine working in sand. The sand wears parts so rapidly that it may not be economical to repair them. This manual assumes that undercarriages are serviced by a good preventive maintenance program.

The main purpose of maintenance checks is to spot potential problems and repair them before major damage is done. Good preventive maintenance is **being observant.**

Each manufacturer supplies an operator's manual for his machine. This manual is the best source of information on daily, routine maintenance checks. The maintenance checks will be divided into time sections such as daily, weekly . . .. or 10 hour, 50 hours . . . .

Fleet owners and large companies often make up their own preventive maintenance check sheets for their mechanics to use. Following are examples of a shift maintenance sheet for a shovel (checks applying to the undercarriage are circled), and a weekly maintenance sheet for a shovel (only undercarriage checks are included).

6:59

TRACK MACHINE UNDERCARRIAGE

AFTON MINE, KAMLOOPS

DATE: ____________________ MECH: ____________________

1900 AL SHOVEL Hr. Reading: 301_____ 302_____ 303_____	301	302	303
• Dipper teeth, caps pins			
• Side cutters, keepers			
• Adapters, "C"-Clamps, wedges			
• Bail pins, equalizer pins, sheaves, keepers			
• Stick/bucket pins, pitch brace pins and keepers			
• Trip cable, chain latch assembly			
• Snubber brake assembly			
• General wear condition			
• Track pads, pins keepers LH ...... RH			
• Sprockets, idlers, lower roller assembly LH ...... RH			
• Propel gearcase bolts, clutch & brake assembly LH ...... RH			
• Lower lube system			
• Hoist ropes, lubrication, condition			
• Auxiliary co-pressor: Drain moisture, check belts			
• Swing & crowd rotor blowers			
• Generator bearings			
• Magnetorque lubrication			
• Drain lube station moisture trips, top up oil as required			
• Check grease & gear cover tanks			
• Shipper shaft side play			
• Saddle block adjustment			
• Gantry & boom pins, keepers			
• Ladders & handrails			

COMMENTS/PARTS USED: ____________________

TRACK MACHINE UNDERCARRIAGE

GIBRALTAR MINES

WEEKLY MECHANICAL PM FOR PH 2100B SHOVELS

DATE .... UNIT NO. .... HOURMETER READING ....

TRUCK FRAME CHECKED BY: ....

1. CIRCLE ROLLERS WEAR—CHECK PINS AND SPACERS FOR WEAR ....
2. RAILS UPPER: .... LOWER: ....
3. CIRCLE TEETH WEAR: ....
4. CHECK SWING PINION WEAR AND NUTS, LOCKS: LH.................. RH ....
5. CHECK PROPEL BRAKE ADJUSTMENT, BAND & DRUM: BRAKE RELEASED SPRING MEASUREMENT 17½" ......
6. CHECK HYD. LINES FOR LEAKS AND DAMAGE. CHECK SOLENOIDS AND PRESS. 600 LBS. ....
7. CHECK CENTER GEAR CASE FOR LEAKS OR DAMAGE: ....
8. CHECK TRANSFER CASE FOR LEAKS AND DAMAGE: ....
9. CHECK PROPEL GEAR CASES FOR LEAKS OR DAMAGE: LH. .... RH. ....
10. CHECK TRAIL CABLES AND SUPPORT FOR DAMAGE: ....

SIDEFRAMES CHECKED BY: ....

1. CHECK TRACK PAD ADJ., PINS AND LOCKS: LH. .... RH. ....
2. ADJUSTING SHIMS, LOCK BARS: LH. .... RH. ....
3. CHECK LOWER ROLLERS, SHAFTS, LOCK COLLARS FOR DAMAGE: LH. .... RH. ....
4. CHECK IDLERS FOR WEAR: LH. .... RH. ....
5. CHECK SPROCKET-LUGS FOR WEAR: LH. .... RH. ....

Daily, routine maintenance checks on track machine undercarriages are much the same for all crawler machines. Walk around and check the machines general condition:

1. Inspect the tracks for broken or missing shoes, loose bolts and any signs of misalignment. Check for proper track tension (discussion following). Track tension and shoe bolts of new tracks should be checked every 10 hours, until the tracks are broken in and the bolts have set.
2. Inspect the sprockets for wear.
3. Inspect the rollers and idlers for wear, leaks and damage.
4. Inspect the guards and covers for damage, and for loose or missing bolts.
5. On shovel tracks, check the track pins and keepers and the track tension.

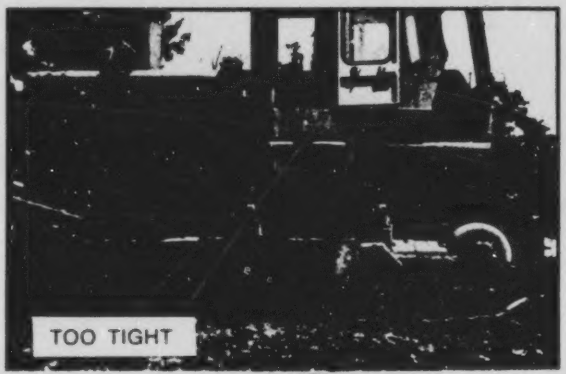
Any minor problems should be repaired and major problems reported.

Also note that track undercarriages should be cleared of debris at the end of the day, a job usually done by the operator. This cleaning is particularly important if the weather is cold and if the machine is working in mud or in material that compacts. Left overnight, the debris could freeze solid in the tracks.

TRACK TENSION: DOZERS, LOADERS, EXCAVATORS

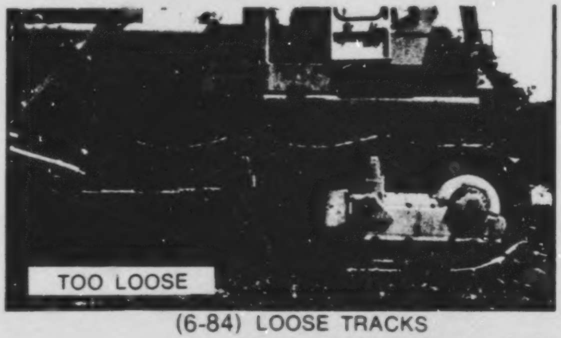
Track tension is the most important running adjustment to be maintained on any track machine. There are several reasons why tracks require frequent adjustment. One is that material, such as clay, builds up on the sprockets and track chain, and the track must be adjusted to make allowance for it. Another reason is that the track stretches due to wear on the pins and bushings. Track stretch is discussed in detail later.

Tight tracks (Figure 6-83) accelerate wear on all undercarriage parts — pins and bushings, links, sprockets, rollers, idlers — and reduce the tractor's horsepower because of increased friction.

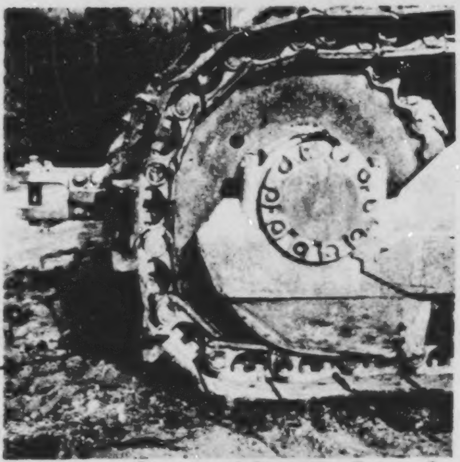


(6-83)
Courtesy of Caterpillar Tractor Co.

Loose tracks (Figure 6-84) will not stay aligned, accelerating wear on the idler and roller flanges. At high speeds a loose track will slip and damage the links, idler and roller flanges. On a side hill or in adverse conditions loose tracks have a tendency to jump off. A loose track is also hard on the sprocket. In reverse the track will bunch up at the back of the sprocket (Figure 6-85), causing sprocket jumping which puts extreme stress on the teeth.



(6-84) LOOSE TRACKS
Courtesy of Caterpillar Tractor Co.

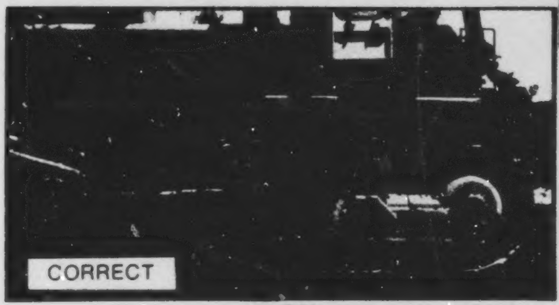


OPERATING IN REVERSE WITH A LOOSE TRACK

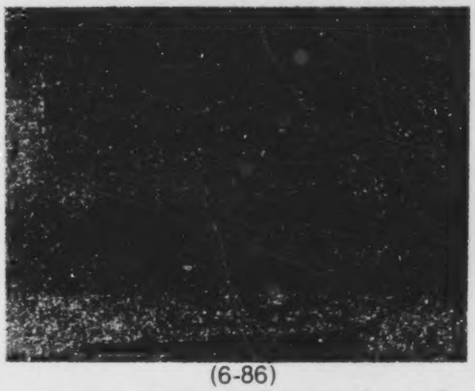
Note the bunching up of the track here.

(6-85)
Courtesy of Caterpillar Tractor Co.

Tracks with correct tension will have some slack to allow for working material build up (Figure 6-85). The most common method of determining if a track has the correct amount of slack is to measure the sag midway between the idler and the first carrier roller, as is illustrated in Figure 6-86. At mid point between the two the track should sag 1½" (38 mm) to 2" (50 mm). If the amount of sag is not right, the track has to be loosened or tightened until the correct sag is obtained.



(6-85)
Courtesy of Caterpillar Tractor Co

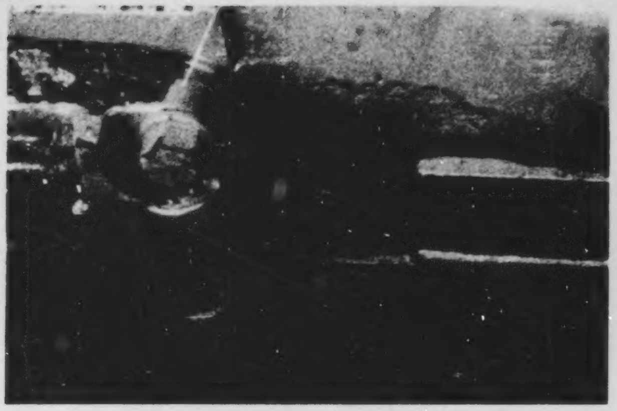


(6-86)
Courtesy of Caterpillar Tractor Co.

In addition to measuring the sag, another method in determining the correct track tension has recently been recommended by the Caterpillar Tractor Co. This method involves measuring the idler movement. The track is fully tightened and a mark is made on the track frame ½" (13 mm) behind the idler bearing support (Figure 6-87). The track is slackened so the idler bearing support goes beyond the mark, and then tightened again so the support is at the mark (Figure 6-88).

When the track is fully tightened measure back half an inch from the idler bearing support and mark.

(6-87)
Courtesy of Caterpillar Tractor Co.



Tighten track so the idler bearing support is at the mark.

(6-88)
Courtesy of Caterpillar Tractor Co

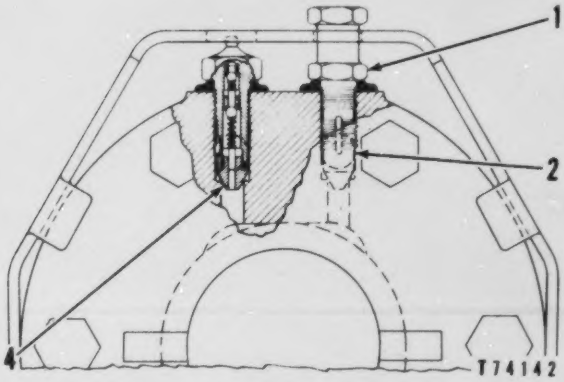
Slackening and Tightening Tracks

To slacken the track, pressure in the track adjuster must be released. As was mentioned earlier most modern machines will have hydraulic track adjusters. However, some machines such as Terex use a combined gas charged recoil mechanism and hydraulic track adjuster that works opposite to the straight hydraulic track adjuster. As well, some smaller or older equipment may use a threaded adjuster. To slacken the track on a particular machine, follow the procedures in the service manual or read the instruction decal conveniently located in the opening in the track frame where the adjuster vent is found. Do not attempt to slacken a track without first reading the instructions.

On hydraulic track adjusters, grease is added through a fill valve (Figure 6-89) to move the idler forward and tighten the tracks. To loosen the track the relief valve is turned allowing grease to escape. As the grease escapes, pressure on the idler is released and it retracts, slackening the track. Figure 6-90 shows the relief valve being turned. On a gas charged recoil cylinder and track adjuster the opposite procedure is used: grease is vented to tighten the track and added to slacken it.

(6-89)

Courtesy of Caterpillar Tractor Co.



RELIEF VALVE AND FILL VALVE
(Later Machines)

1—Relief valve. 2—Vent hole. 4—Fill valve.

(6-89)

Courtesy of Caterpillar Tractor Co.

(6-90) OPEN THE HYDRAULIC RELIEF VALVE

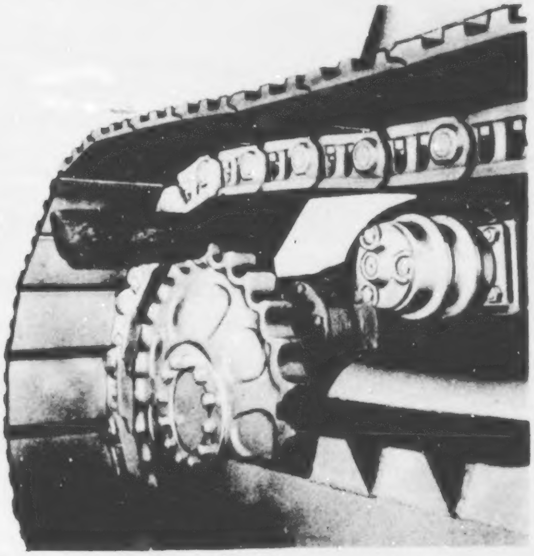
Courtesy of Caterpillar Tractor Co.

Safety Precautions With Track Adjusters

1. When the track adjuster is extended to its limit and the track is severely worn, it is possible to remove the master pin without venting the adjuster. Don't do it. Always vent the cylinder no matter how slack the track is because there can still be high (i.e., dangerous) pressure within the adjuster cylinder.
2. When exhausting the pressure, keep your face away from the vent hole, and as an added precaution cover the vent with a rag. If you wish to see if grease is escaping look at the cylinder to see if the piston rod is moving to the rear toward the recoil spring or look at the track to see if it has loosened.

3. To ensure complete retraction of the hydraulic adjuster piston:
   - — place a large piece of wood or a track pin in the sprocket (Figure 6-91)
   - — turn the vent screw one turn counter clockwise
   - — back the machine up

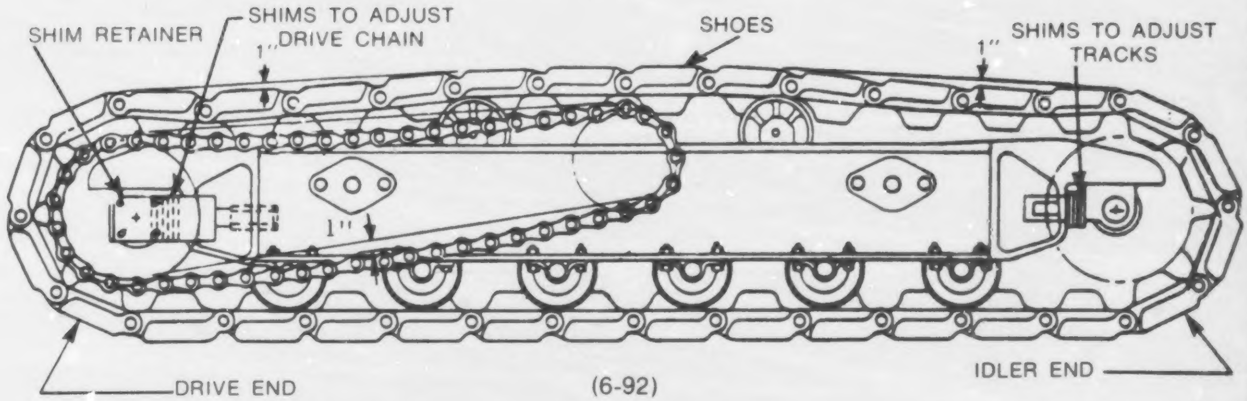
The track will then be completely slackened. To remove the block of wood, move the machine forward.



(6-91)
Courtesy cf Massey Ferguson Inc

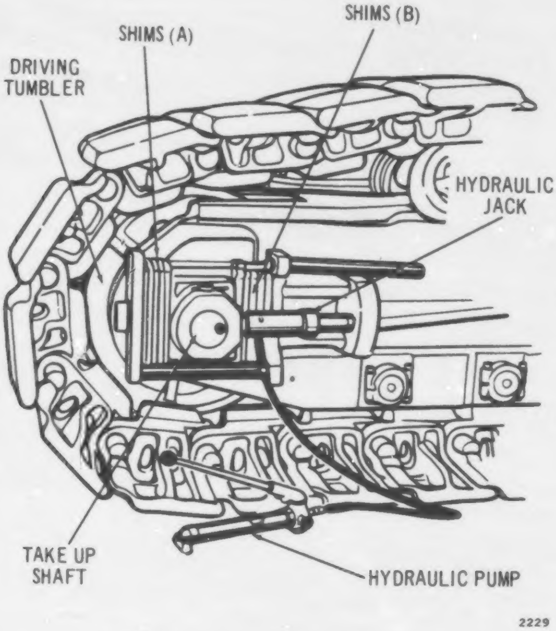
TRACK TENSION: SHOVELS, CRANES

Correct tension on shovel or crane tracks can be set by a similar sag method described for dozers and loaders. In Figure 6-92 a one inch sag is recommended for both the drive chain and tracks. Note that on shovels or cranes having mechanical chain drives, the drive chain as well as the tracks must have the correct tension. When adjusting to get the correct tensions always adjust the drive chain first. The adjusting mechanisms are usually two sets of shims as seen in Figure 6-92. Shovels or cranes that have direct drive may also have either a set of shims to adjust the tracks or a track adjuster.



(6-92)

Tracks of large shovels with gear or hydraulic drives are adjusted by shimming the idler tumbler as shown in Figure 6-93. When maximum adjustment has been reached with the shims, it is recommended that the track be broken and one shoe removed. A hydraulic jack is necessary to push the take-up shaft and tumbler assembly outward.


SHIMS (B)
SHIMS (A)
DRIVING TUMBLER
HYDRAULIC JACK
TAKE UP SHAFT
HYDRAULIC PUMP
2229

(6-93) ADJUSTING TRACK TENSION

Courtesy of Harnishfeger Corporation, P&H

QUESTIONS — UNDERCARRIAGE DAILY, ROUTINE MAINTENANCE

1. What is the best source of information for the daily, routine maintenance checks that should be carried out on a machine?
2. Why are maintenance checks necessary? List at least four things that should be checked during a daily walk around inspection of the undercarriage.
3. What is a common method used to measure track tension?
4. Briefly explain why correct track tension is important.
5. On a hydraulic track adjuster grease is added to __________ the track and __________ to loosen it. On a gas-charged combined recoil mechanism and track adjuster grease is __________ to slacken the track and vented to __________ it.
6. What precautions must be observed when slackening a track equipped with a hydraulic track adjuster?
7. Some shovels and cranes have two "chains" on each side, a drive chain and a track chain. If both needed adjusting, which one must be adjusted first? What is the usual method of adjustment?

SCHEDULED MAINTENANCE

UNDERCARRIAGE WEAR

Track rollers, idlers, carrier rollers, sprockets and track chains (links pins and bushings) wear out like tires on trucks and eventually have to be replaced.

The point of a good preventive maintenance program is to maintain the undercarriage so that these components all wear out at approximately the same time. This is called matching wear on components. Matching wear is not always possible because various stress factors can cause one component to wear faster than another. Some of these factors are:

Environment — Rocky terrain obviously causes more wear than soft earth. Sand and other gritty materials act as abrasives and can cause rapid wear.

Type of Work — The heaviness of the work involved; steep grades, side hills, all will affect wear.

Operator — Operators have different working and maintenance habits which will affect wear. Some operators are much harder on machines than others.

Speed — The faster a machine goes the harder it is on the undercarriage.

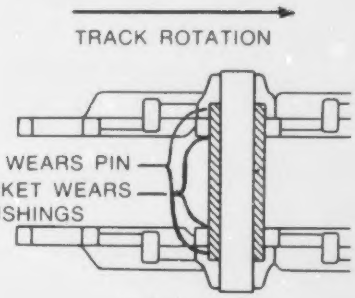
As was stated earlier, the undercarriage accounts for a large percentage of the cost of maintaining a track machine. Knowing this, tractor companies have track specialists who travel around the province doing undercarriage inspections "free of charge" with the intention, of course, of selling service.

Before looking at the methods of measuring the wear and alignment of undercarriage components, the subject of why and how a component wears will be discussed.

PIN AND BUSHING WEAR

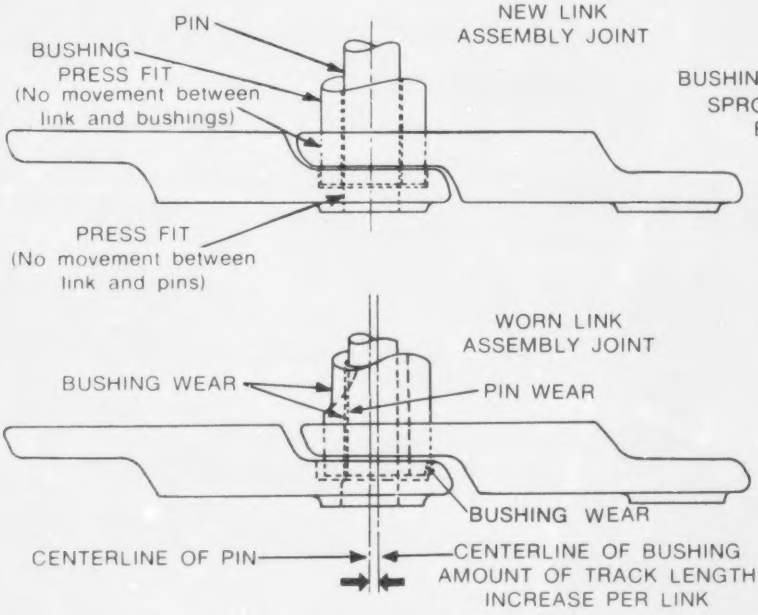
Tracks are subjected to the severest wear of any of the undercarriage components and if not maintained they can cause accelerated wear to the other components.

The sealed track (as opposed to the sealed and lubricated track) runs dry with metal to metal contact, causing wear to the pins, bushings and links (Figure 6-94). External wear occurs to the bushing on the outer surface area contacted by the sprocket tooth, an area amounting to about 1/3 of the bushing circumference. Internal wear occurs to the pin and inside of the bushings and to the end of the bushing where it fits into the link counter bore (Figure 6-95).


TRACK ROTATION
BUSHING WEARS PIN
SPROCKET WEARS BUSHINGS

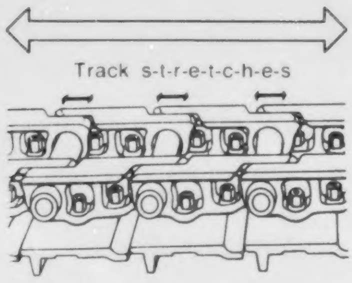
(6-94)

Courtesy of John Deere Ltd


PIN
BUSHING
NEW LINK ASSEMBLY JOINT
PRESS FIT (No movement between link and bushings)
PRESS FIT (No movement between link and pins)
WORN LINK ASSEMBLY JOINT
BUSHING WEAR
PIN WEAR
BUSHING WEAR
CENTERLINE OF PIN
CENTERLINE OF BUSHING
AMOUNT OF TRACK LENGTH INCREASE PER LINK

(6-95) PIN AND BUSHING WEAR Courtesy of International Harvester

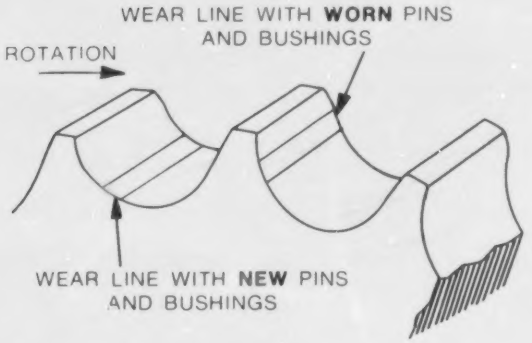
As pins and bushings wear, the track pitch (the distance from pin center to pin center) increases and thus the track stretches (Figure 6-96). When the track is stretched, the track pitch and the sprocket pitch no longer match. Thus the bushing is picked up sooner by the sprocket tooth, causing the wear line on the tooth to rise (Figure 6-97). A raised wear line on the drive side of sprocket teeth is a sure indication of pin and bushing wear. When bushings ride up on the teeth they also cause rotating wear to the other side of the tooth as the bushing exits the tooth. Figure 6-98 details sprocket wear.



WORN PINS AND BUSHINGS

(6-96)

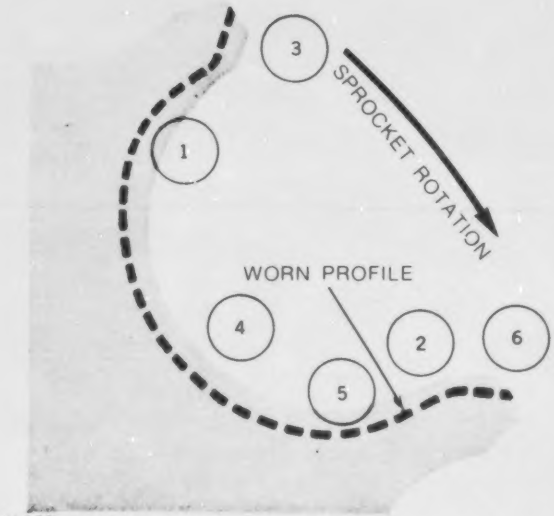
Courtesy of International Harvester


WEAR LINE WITH **WORN** PINS AND BUSHINGS
ROTATION
WEAR LINE WITH **NEW** PINS AND BUSHINGS

X2663

(6-97) WEAR LINES ON SPROCKET TEETH

Courtesy of John Deere Ltd



(6-98) Courtesy of John Deere Ltd

1. Drive Side Wear — when operating forward.
2. Reverse Drive Side Wear — when operating in reverse.
3. Climbing Wear — result of increased track pitch.
4. Root Wear — when bushing slides from side to side.
5. Rotating Wear — when bushing rotates as it leaves (forward) or enters (reverse) the sprocket.
6. Reverse Drive Side Tip Wear — when sprocket pitch is greater than track pitch.

Another damaging effect of worn pins and bushings is a snakey track. The space created by the wear between the pins and bushings allows the track to cock, causing it to wander from side to side, or snake. A snakey track leads to rapid wear on the links, idler, carrier and track roller flanges, and track guiding guards.

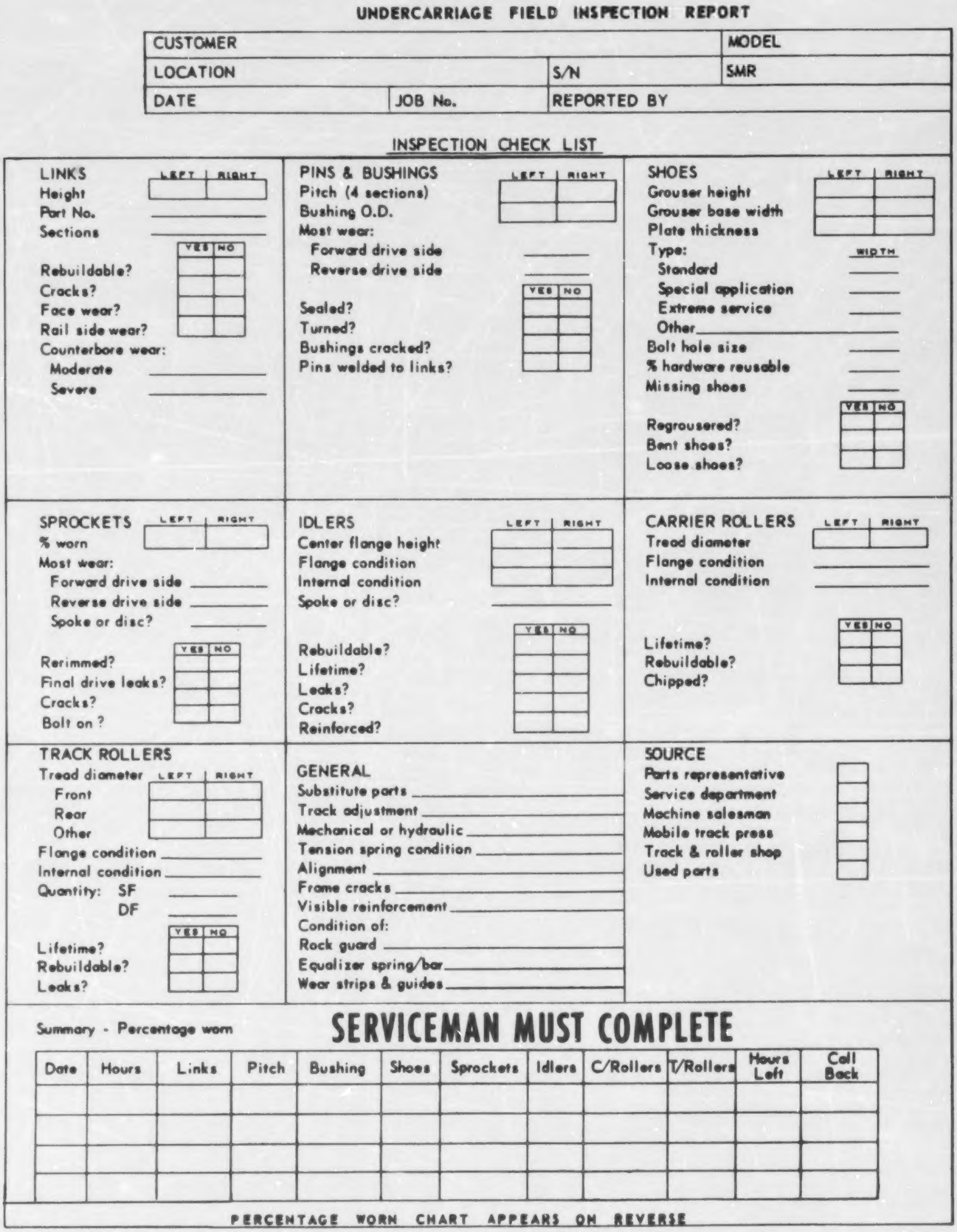
Track stretch can be compensated for by tightening the track with the track adjuster. Eventually though, the track adjuster will not be able to tighten the tracks any further, and the stretched track can only be corrected by turning the pins and bushings 180°. Turning pins and bushings will be discussed later.

Undercarriage Wear On Sealed and Lubricated Tracks

Lubricated tracks appear to reduce track and undercarriage wear significantly. Track stretch is virtually eliminated because there is very little pin and bushing wear. The service-life of sprockets, roller flanges, idlers and links is increased because there is less stress on them. Other advantages of lubricated tracks include quieter machine operation, and reduced friction which gives more efficient use of engine horsepower. Lubricated tracks are not the answer to all track and track related problems, but reports on them to date indicate an extended life of tracks and other undercarriage components.

MEASURING UNDERCARRIAGE WEAR

An undercarriage component is measured and recorded on a field check sheet. This measurement is then looked up on a Percentage Worn Chart (usually accompanying the field sheet) to find the percentage the component is worn. Percentage worn chart figures are calculated to a **rebuild limit,** i.e., when a part is 100 percent worn, it is ready to be rebuilt. If let go any longer the part may not be economical to rebuild. Note that because a part is beyond the rebuild limit (over 100%), it is not necessarily worn out. The part may have many hours of service left. Being over the rebuild limit simply means that from a cost-benefit point of view it is better to let the part run out its service life than to rebuild it. Following is an example of a field check sheet and a percentage worn chart (courtesy of Caterpillar Tractor Co.) Note that the chart is given only as an example and should not be used to calculate component wear because the figures may be out of date.



UNDERCARRIAGE FIELD INSPECTION REPORT

CUSTOMER			MODEL
LOCATION		S/N	SMR
DATE	JOB No.	REPORTED BY	

INSPECTION CHECK LIST

LINKS

	LEFT	RIGHT
Height		

Part No. ______

Sections ______

	YES	NO
Rebuildable?		
Cracks?		
Face wear?		
Rail side wear?		

Counterbore wear:

Moderate ______

Severe ______

PINS & BUSHINGS

	LEFT	RIGHT
Pitch (4 sections)		
Bushing O.D.		

Most wear:

Forward drive side ______

Reverse drive side ______

	YES	NO
Sealed?		
Turned?		
Bushings cracked?		
Pins welded to links?		

SHOES

	LEFT	RIGHT
Grouser height		
Grouser base width		
Plate thickness		

Type:	WIDTH
Standard	
Special application	
Extreme service	

Other ______

Bolt hole size ______

% hardware reusable ______

Missing shoes ______

	YES	NO
Regrousered?		
Bent shoes?		
Loose shoes?		

SPROCKETS

	LEFT	RIGHT
% worn		

Most wear:

Forward drive side ______

Reverse drive side ______

Spoke or disc? ______

	YES	NO
Rerimmed?		
Final drive leaks?		
Cracks?		
Bolt on ?		

IDLERS

	LEFT	RIGHT
Center flange height		
Flange condition		
Internal condition		

Spoke or disc? ______

	YES	NO
Rebuildable?		
Lifetime?		
Leaks?		
Cracks?		
Reinforced?		

CARRIER ROLLERS

	LEFT	RIGHT
Tread diameter		

Flange condition ______

Internal condition ______

	YES	NO
Lifetime?		
Rebuildable?		
Chipped?		

TRACK ROLLERS

Tread diameter	LEFT	RIGHT
Front		
Rear		
Other		

Flange condition ______

Internal condition ______

Quantity: SF ______

DF ______

	YES	NO
Lifetime?		
Rebuildable?		
Leaks?		

GENERAL

Substitute parts ______

Track adjustment ______

Mechanical or hydraulic ______

Tension spring condition ______

Alignment ______

Frame cracks ______

Visible reinforcement ______

Condition of:

Rock guard ______

Equalizer spring/bar ______

Wear strips & guides ______

SOURCE

Parts representative ☐

Service department ☐

Machine salesman ☐

Mobile track press ☐

Track & roller shop ☐

Used parts ☐

Summary - Percentage worn

SERVICEMAN MUST COMPLETE

Date	Hours	Links	Pitch	Bushing	Shoes	Sprockets	Idlers	C/Rollers	T/Rollers	Hours Left	Call Back

PERCENTAGE WORN CHART APPEARS ON REVERSE

Courtesy of Caterpillar Tractor Co.

TRACK MACHINE UNDERCARRIAGE

UNDERCARRIAGE PERCENTAGE WORN CHART

A. All Measurements are in inches
B. All % are precentage Worn figures
C. Pin & bushing – 17'' scale used if abrasive conditinns
consult .19'' scale – CTS Handbook

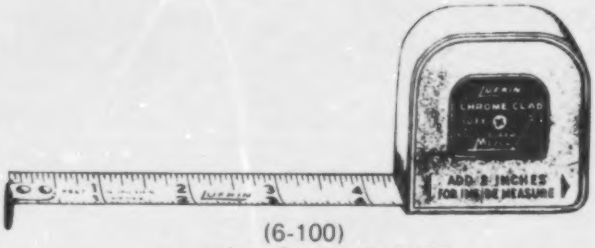
For Additional Information Consult Your Custom Track Service Handbook

MODEL TRACK PITCH	LINKS				PIN & BUSHING PITCH	%	BUSHING O.D.		SHOES				IDLER		CARRIER ROLLER	%	TRACK ROLLERS			
	9S1927-28	%	7S3925-26 1S6323-24	%					LOW.MOD. 7S9294 7S9104	%	HI.IMPACT 4M3883 8M5664	%		%			HIGH RAIL 9S1927-28	%	7S3925-26 1S6323-24	%
D9G 10.25''	6.12	0	5.69	0	41.04	0	3.37	0	3.44	0	3.44	0	.88	0	8.62	0	10.62	0	10.62	0
	6.00	27	5.60	25	41.15	23	3.34	25	2.80	26	2.90	28	.96	29	8.46	25	10.42	22	10.46	22
	5.88	53	5.50	52	41.30	54	3.31	50	2.20	51	2.40	54	1.04	52	8.30	51	10.18	49	10.26	49
	5.78	76	5.42	75	41.40	75	3.28	75	1.60	75	2.00	74	1.14	76	8.10	76	9.94	75	10.06	76
	5.62	100	5.31	100	41.52	100	3.25	100	1.00	100	1.50	100	1.24	100	7.57	100	9.62	100	9.87	100
D9 9.00''	2M1623-24	%				%			2S6358 7S9084	& %	8H4268 1S1926			%		%			2M1623-24	%
	5.25	0			36.04	0	3.19	0	3.06	0	3.06	0	.88	0	8.62	0			10.62	0
	5.16	27			36.15	23	3.16	25	2.50	27	2.60	29	.96	29	8.46	25			10.46	23
	5.08	51			36.30	54	3.13	50	2.00	51	2.30	49	1.04	52	8.30	51			10.26	52
	5.00	75			36.40	75	3.10	75	1.50	76	1.90	74	1.14	76	8.10	76			10.10	75
	4.90	100			36.52	100	3.07	100	1.00	100	1.50	100	1.24	100	7.87	100			9.93	100
D8H-983 9.00''	7S9181-82	%	1S4033-34	%		%		%	2S6345	%	7S9093	%		%		%	7S9181-82	%	1S4033-34	%
983 TRACKSHOES USE CTS HANDBOOK	5.41	0	5.25	0	36.04	0	3.04	0	3.06	0	3.06	0	.94	0	7.50	0	10.00	0	10.00	0
	5.30	24	5.16	23	36.15	23	3.01	25	2.60	22	2.70	23	1.02	28	7.34	25	9.76	27	9.80	25
	5.18	51	5.06	48	36.30	54	2.98	50	2.00	51	2.30	49	1.10	51	7.18	51	9.56	49	9.60	50
	5.06	78	4.94	78	36.40	75	2.95	75	1.60	76	1.90	74	1.20	74	6.98	76	9.32	76	9.40	76
	4.91	100	4.83	100	36.52	100	2.92	100	1.00	100	1.50	100	1.31	100	6.75	100	9.00	100	9.16	100
D8 8.00''	1S8839-40	%	7H3799800	%		%		%	7H4739	%	7H4739	%		%		%	1S8839-40	%	7H3799800	%
	4.97	0	4.88	0	31.98	0	2.75	0	2.81	0	2.81	0	.88	0	7.50	0	9.06	0	9.06	0
	4.88	27	4.82	23	32.10	26	2.72	26	2.34	26	2.46	27	.94	22	7.34	25	8.90	26	8.90	29
	4.80	50	4.74	52	32.25	56	2.69	50	1.92	49	2.16	50	1.04	52	7.18	51	8.74	52	8.78	50
	4.72	74	4.64	77	32.35	77	2.66	76	1.44	76	1.80	77	1.14	76	6.98	76	8.54	75	8.62	74
	4.59	100	4.55	100	32.46	100	2.63	100	1.00	100	1.50	100	1.24	100	6.75	100	8.31	100	8.40	100
D7F 8.50''	8S2589-90	%	2S1749-50	%		%		%	1P6807	%	9M5930	%		%		%	8S2589-90	%	2S1749-50	%
TRACKSHOE 1M8798 SEE CTS BOOK	4.94	0	4.75	0	34.04	0	2.81	0	2.81	0	2.81	0	.88	0	7.50	0	8.75	0	8.75	0
	4.84	25	4.66	27	34.16	23	2.78	25	2.34	26	2.46	27	.94	22	7.34	25	8.56	23	8.60	22
	4.74	51	4.58	52	34.30	54	2.75	50	1.92	49	2.16	50	1.02	47	7.18	51	8.32	52	8.40	51
	4.64	76	4.50	76	34.40	75	2.72	76	1.44	76	1.80	77	1.14	76	6.98	76	8.12	77	8.24	74
	4.50	100	4.40	100	34.52	100	2.69	100	1.00	100	1.50	100	1.24	100	6.75	100	7.87	100	8.05	100
D7-977 8.00''	1S8433-34 1S1863-64	%				%		%	7M788	%	7M732	%		%		%			1S1863-64 1S6433-34	%
TRACKSHOES 8S4468 & 3S8629 SEE CTS HANDBOOK	4.63	0			31.98	0	2.62	0	2.81	0	2.81	0	.88	0	7.50	0			8.75	0
	4.54	26			32.10	25	2.59	25	2.34	26	2.46	27	.94	22	7.34	25			8.56	26
	4.46	49			32.25	56	2.56	50	1.92	49	2.16	50	1.04	52	7.18	51			8.36	53
	4.36	77			32.35	77	2.53	75	1.44	76	1.80	77	1.14	76	6.98	76			8.20	75
	4.25	100			32.46	100	2.50	100	1.00	100	1.50	100	1.24	100	6.75	100			8.00	100
D6C 8.00''	7S0109-10 8S5231-32	%	9M5627-28	%		%		%	4S7687	%	7S9555	%		%		%	7S9109-10 8S5231-32	%	9M5627-28	%
SPECIAL APP SHOES SEE CTS HANDBOOK	4.65	0	4.50	0	31.98	0	2.62	0	2.38	0	2.38	0	.88	0	7.38	0	8.25	0	8.25	0
	4.56	25	4.44	21	32.10	25	2.59	25	2.02	26	2.14	27	.94	30	7.22	25	8.06	26	8.10	25
	4.48	48	4.36	49	32.25	56	2.56	50	1.72	49	1.96	48	.98	49	7.06	51	7.90	48	7.94	53
	4.38	76	4.28	77	32.35	77	2.53	75	1.36	74	1.72	77	1.06	77	6.86	76	7.70	75	7.82	73
	4.27	100	4.20	100	32.46	100	2.50	100	1.00	100	1.50	100	1.13	100	6.63	100	7.50	100	7.66	100
D6B-951B 6.75''	2S5959-60	%	2M8863-64	%		%		%	4S7668 4S7664	%	5K9773	%		%		%	MCS ROLLER RIMS 2S5959-60 LINKS		DHS ROLLER RIMS 2S5959 60 LINKS	
	4.00	0	3.91	0	26.98	0	2.12	0	2.12	0	.69	0	.78	9	6.75	0	8.00	0	8.00	0
	3.92	24	3.86	21	27.10	25	2.09	25	1.80	26	.58	25	.84	30	6.64	24	7.88	23	7.84	24
	3.84	49	3.78	53	27.25	56	2.06	50	1.48	52	.46	50	.90	57	6.52	49	7.72	55	7.64	53
	3.76	73	3.70	75	27.35	77	2.03	75	1.20	74	.36	75	.96	77	6.40	75	7.60	75	7.48	77
	3.66	100	3.61	100	27.46	100	2.00	100	.88	100	.25	100	1.03	100	6.25	100	7.41	100	7.32	100
D5-955K 6.91''	5S683-84 1P3281-82	%				%		%	STANDARD 5S820	%	TR. GROUSER 6K1910	%		%		%	ROLLER MCS RIMS	%	ROLLER DHS RIMS	%
	4.06	0			27.67	0	2.31	0	2.25	0	1.00	0	.78	0	6.75	0	8.00	0	8.00	0
	3.98	23			27.80	27	2.28	25	1.92	24	.80	26	.82	20	6.64	24	7.84	26	7.80	27
	3.88	52			27.90	48	2.25	50	1.56	50	.64	47	.88	49	6.52	49	7.68	52	7.64	49
	3.80	75			28.05	79	2.22	75	1.24	74	.44	74	.96	77	6.40	75	7.48	76	7.44	76
	3.69	100			28.15	100	2.19	100	.88	100	.24	100	1.03	100	6.25	100	7.26	100	7.26	100
D4-941 6.75''	7K1825-26	%	5K9423-24 5K9457-58	%		%		%	4K7092 3S2778	%	5K6966	%		%		%	ROLLER MCS RIMS	%	ROLLER DHS RIMS	%
BUSHING LARGE O.D. ONLY GIVEN	3.75	0	3.66	0	26.98	0	2.12	0	1.88	0	.69	0	.68	0	5.88	0	8.00	0	8.00	0
	3.69	24	3.60	24	27.10	25	2.09	25	1.60	25	.58	25	.72	20	5.76	26	7.88	26	7.88	24
	3.62	52	3.53	52	27.25	56	2.06	50	1.32	50	.46	52	.78	49	5.64	51	7.78	49	7.74	52
	3.56	76	3.47	76	27.35	77	2.03	75	1.04	74	.36	75	.86	77	5.52	77	7.66	75	7.62	76
	3.50	100	3.41	100	27.46	100	2.00	100	.75	100	.25	100	.93	100	5.38	100	7.50	100	7.50	100

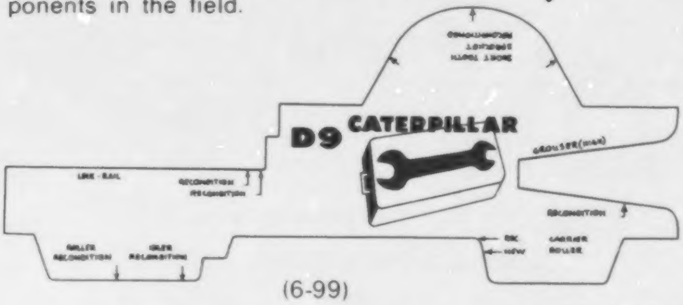
Courtesy of Caterpillar Tractor Co

Measuring Tools

Plastic track wear gauges (Figure 6-99) are available for many machines. Gauges are not always the most accurate measuring tool, but they are handy and easy to use. A ruler, depth gauge, tape measure, and set of outside calipers (Figure 6-100) will give reasonably accurate measurement of undercarriage components in the field.



(6-100)
72" STEEL TAPE MEASURE
Courtesy of Caterpillar Tractor Co.



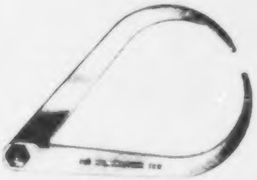
(6-99)

Courtesy of Caterpillar Tractor Co.

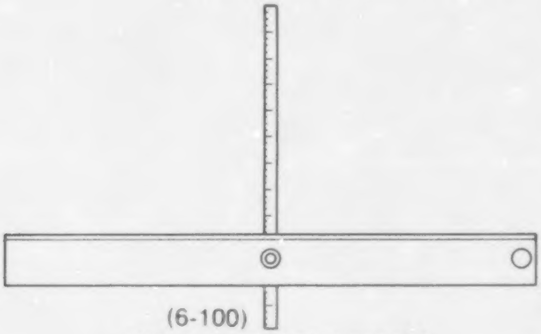
12" STEEL SCALE

(6-100)

Courtesy of Caterpillar Tractor Co.



12" OUTSIDE CALIPERS
(6-100)
Courtesy of Caterpillar Tractor Co.



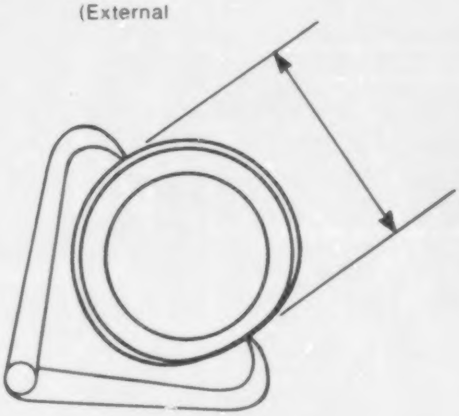
(6-100)
WIDE BASE DEPTH GAUGE
(Lufkin 509E depth gauge shown here)
Courtesy of Caterpillar Tractor Co.

To perform a track measurement inspection, move the machine to level, firm ground, clean any accumulated material from around the tracks, and do a walk around check. Before measuring the tracks check the top part of the bushing with your finger to make sure the pins and bushings have not already been turned.

External Bushing Wear

Using outside calipers measure the bushings (Figure 6-101). Be sure to take the measurement across the worn diameter of the bushing. Measure three or four bushings in different parts of the track to obtain an average measurement.

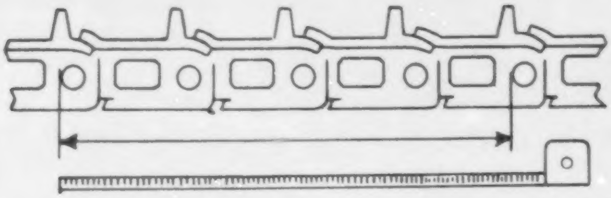
BUSHINGS
(External



(6-101)

Internal Pin and Bushing Wear

To take up the slack in the track, place a block of wood or a steel pin in a sprocket tooth and then reverse the tractor. Measure from the side of one pin to the same side of the fifth pin away. This measurement will include four links (Figure 6-102). The pins measured should not be within two of the master pin, and should be taken on a section of the track that is not on the ground.

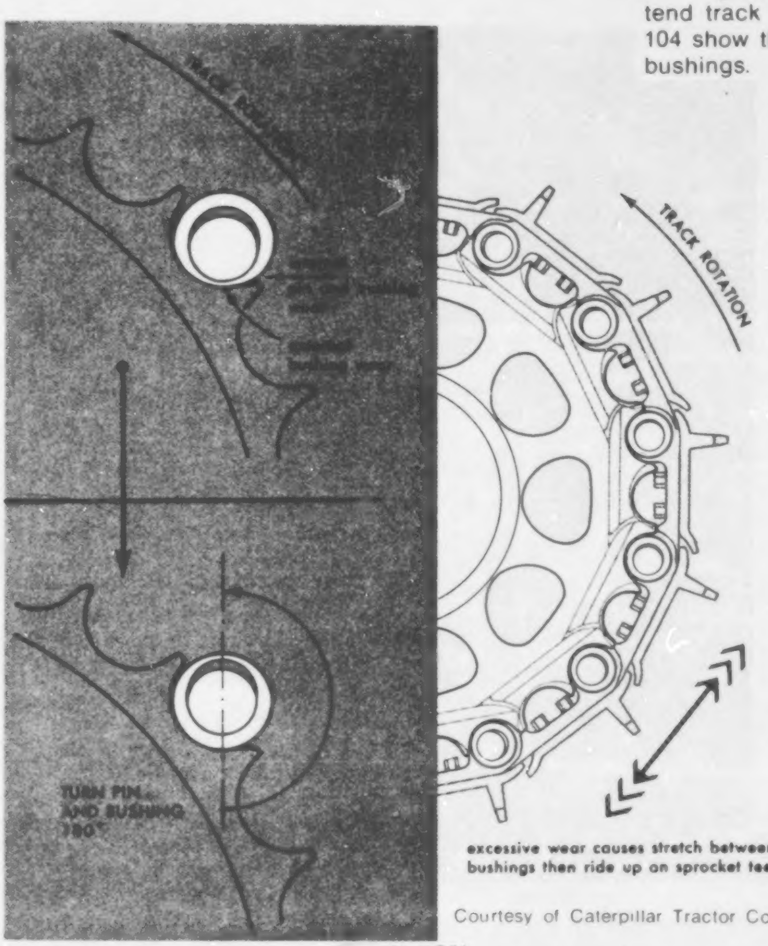


(6-102)

Divide the measurement by four, the number of links included, to get a figure for the present track pitch. Look up this figure on the wear chart to find the percentage the pitch is worn. Note that some wear charts such as the one shown give a four link measurement, and so it is not necessary to divide by four.

The same measurement procedure should be repeated on the master track section to determine whether the master pin and bushing should be replaced. The master pin and bushing always wear faster than the others because there is a greater clearance between them, necessary for breaking and connecting the track. Of course, the second measurement would not be applicable where a master link is used rather than a master pin.

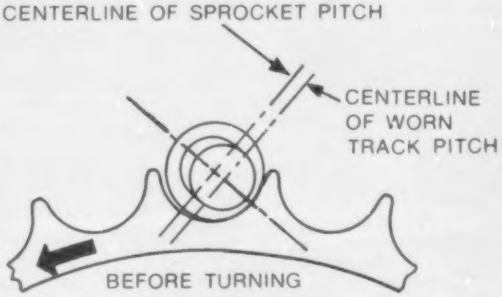
If the track pitch is not beyond wear limits and if the bushings are not cracked, the pins and bushing can be pressed out and turned 180°. Turning the pins and bushings will greatly extend track service life. Figures 6-103 and 6-104 show the effects of rotating the pins and bushings.



excessive wear causes stretch between bushings; bushings then ride up on sprocket teeth

Courtesy of Caterpillar Tractor Co

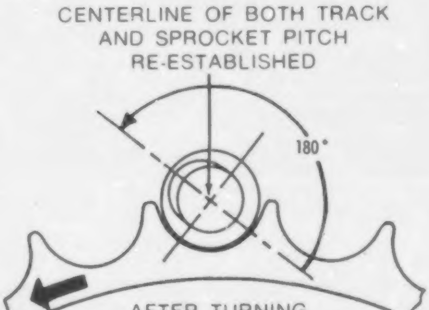
(6-103)



BEFORE TURNING

X2669

(6-104)



AFTER TURNING

(6-104)

Rotating Worn Pins and Bushing 180 Degrees

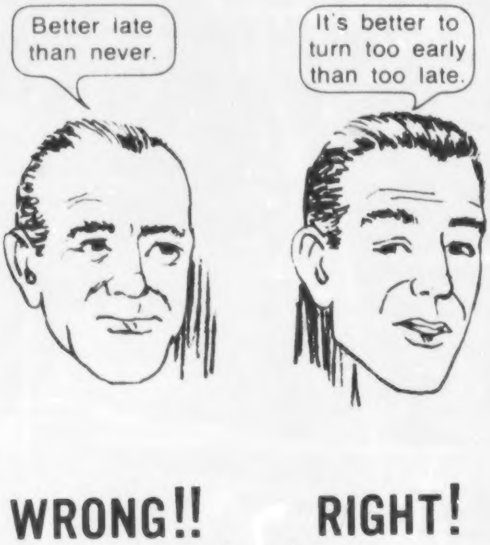
Courtesy of John Deere Ltd

It should be pointed out that not all machines will have their pins and bushings turned. Some abrasive working conditions wear parts very quickly and make turning uneconomical. Also, some companies have a policy of running the undercarriage to destruction doing little or no repair.

When To Turn Pins and Bushings

Correct timing of turning pins and bushings is important.

WHEN DO YOU TURN PINS AND BUSHINGS?


Better late than never.
It's better to turn too early than too late.
WRONG!!
RIGHT!

(6-105)

There are three generally accepted methods for determining when to turn pins and bushings. The first method consists of keeping accurate measurements of track stretch and consulting wear charts, as discussed earlier. This method requires no past experience of how long pins and bushings and links last. It is the most reliable of the three methods and is the only dependable one for tractors working in various environments.

The second method consists of making the number of service hours before turning equal to the service hours after turning. Method two implies that you have past experience with the machine in similar working conditions, that is, you have applied method one and know the number of hours before turning and after turning. For example, if by using method one you have 800 hours before turning, 1100 hours after and 1900 hours total, the next time you should try turning at 1000 hours. You will probably get 1000 hours after turning for a total of 2000 plus hours.

The third method involves turning the pins and bushings at one half the expected link life. Method three assumes that from past experience you know what link life will be and also assumes that the machine is working in similar conditions. This method will not usually work if link life exceeds pin and bushing life by more than 50 percent.

Example Problems For Method Three:

1. Normal link life .... 3000 hours

   Normal pin and bushing life (without turning) .... 2000 hours

   Solution: Turn at 1500 hours — pins and bushings should last 1500 hours after turning to give a total of 3000 hours.

2. Normal link life .... 3000 hours

   Normal pin and bushing life (no turning) .... 1600 hours

   Solution: In general replacing pins and bushings at 1500 hours rather than turning would be best.

3. Normal link life .... 2400 hours

   Normal pin and bushing life (no turning) .... 2000 hours

   Solution: Turn at 1200 hours — pins and bushings will easily make it another 1200 hours.

The advantage of this third method is that pin and bushing life is matched to link life while track stretching is held to a minimum. In the last example:

1. pin and bushing life is extended 400 hours.
2. the links, pins and bushings can be serviced at the same time.
3. the track never gets badly stretched.
4. sprocket life can be extended up to 100 percent.

Some owners question the cost of turning. However, in most cases the expense is justified on a cost per hour basis. The economics of turning can be figured in this way: divide the initial cost of pins and bushings by the number of hours they'll last if run to destruction. Add together the initial cost of pins and bushings and the cost of turning them. Divide this combined cost by the total number of hours the customer will get by turning. This will give you the cost per hour of turning.

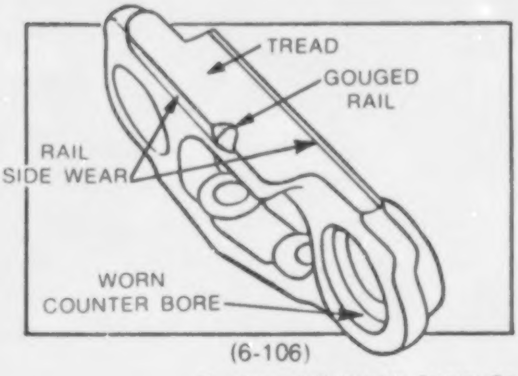
Also, from a cost standpoint, it cannot be over-looked that running pins and bushings to destruction increases wear on links, rollers, idlers and particularly sprockets. The undercarriage works as a unit. Excessive wear in one area, particularly pins and bushings, will cause accelerated wear on the other components.

Link Wear

Links form the surface or rails that a machine runs on. They are rugged parts that take a lot of abuse especially if the tracks are allowed to run loose, or if the machine is run at high speed. Normal link wear is caused by the links contacting the rollers and idlers.

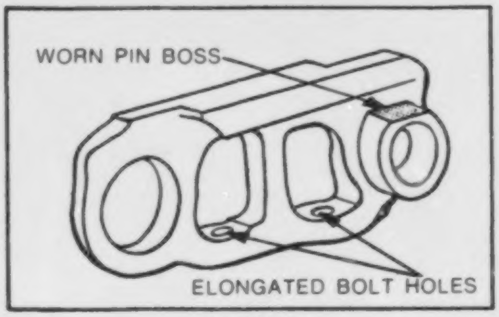
Types of link wear are (Figure 6-106):

- Rail tread wear
- Rail side wear
- Rail inside gouged
- Pin boss worn
- Bolt holes wallowed out or elongated (shoes run loose)
- Worn counter bore.



(6-106)

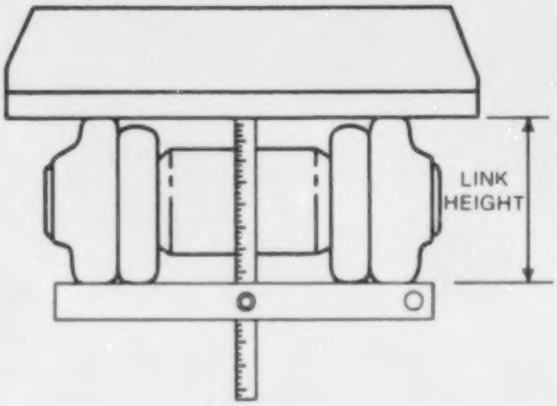
Courtesy of Caterpillar Tractor Co.



(6-106)

Courtesy of Caterpillar Tractor Co.

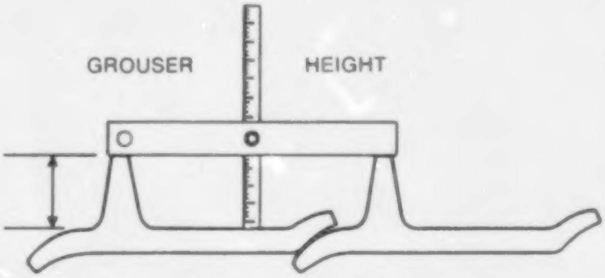
Link tread wear can be determined by comparing the height of the worn links (Figure 6-107) with the height when new. If link rebuilding is intended, check the worn chart for the rebuild limit.



(6-107)

Track Shoe Wear (Grouser Heighth)

Rest the crossbar of a depth gauge, or a steel rule, across two grousers (Figure 6-108). Measure from the bottom of the crossbar or rule to the shoe plate to determine the grouser height. Grouser wear is the difference between this height and the height when new.



(6-108)

Shoes should not be allowed to wear too much if rebuilding is intended. As the grouser wears, the shoe loses its beam strength and will bend. Also, once worn beyond the depth of the hardening, the grouser will wear rapidly. Check the worn chart for the grouser rebuild limit.

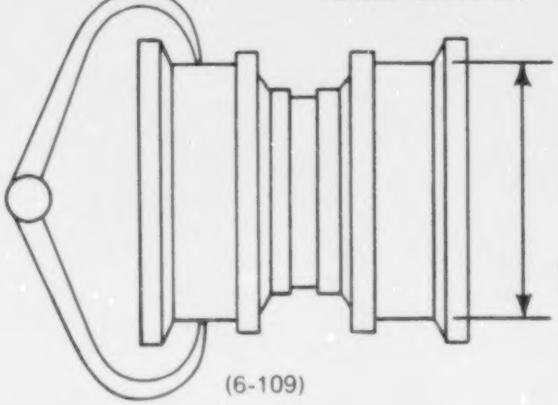
Track Roller Wear

Roller diameter is calculated by calipering the roller tread (Figure 6-109). The worn diameter, when subtracted from the new roller diameter, gives the amount of surface tread wear. Check the worn chart for the track roller rebuild limit. Track roller wear is shown in Figure 6-110.

If rock guards are installed roller diameter cannot be measured with a caliper. Here is an alternate method (Figure 6-111):

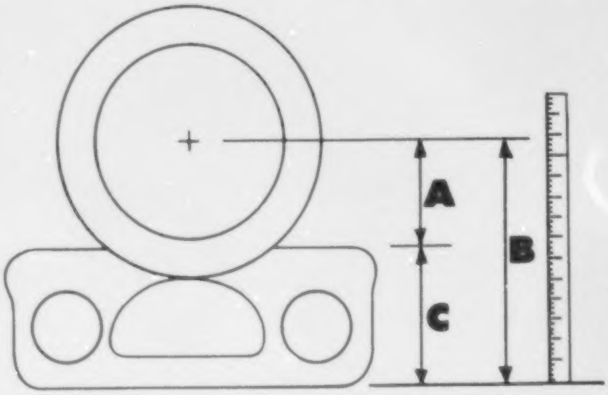
Measure vertically from the shoe to the center of the roller shaft to get "B". Subtract link height "C" to get roller radius "A". Cocking or tilting the shoe, or a bent shoe, will cause inaccuracy. Take three or more measurements and average them. Example: If the roller shaft center to shoe height, "B" is 9 inches and rail height, "C" is 5 inches, then roller radius, "A" will be 4 inches. Taking this radius and doubling it will give the worn diameter of the roller, 8 inches.

ROLLER DIAMETER

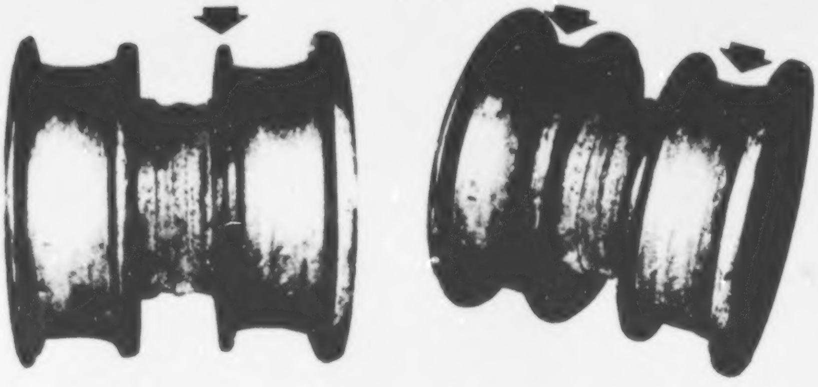


(6-109)

ROLLER RADIUS
(on machine with roller guards installed)



(6-111)



Side hill operation caused this roller flange wear.

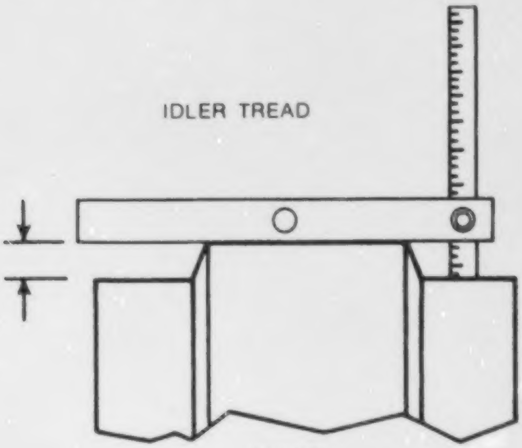
Contact with link rails caused this roller tread wear . . .

(6-110)
Courtesy of Caterpillar Tractor Co.

Idler and Carrier Roller Wear

Idler tread wear can be found by measuring the present height of the center flange and comparing it with its height when new (Figure 6-112). Check the wear chart for the idler rebuild limit.

Carrier Roller tread wear can be found by calipering the tread surface and comparing it with the tread surface when new. Check the wear chart for the carrier roller rebuild limit.



(6-112)

Sprocket Wear

Sprockets can be measured with a wear gauge (Figure 6-113), but generally a visual check of the sprocket for wear marks on the teeth will reveal how badly it is worn.

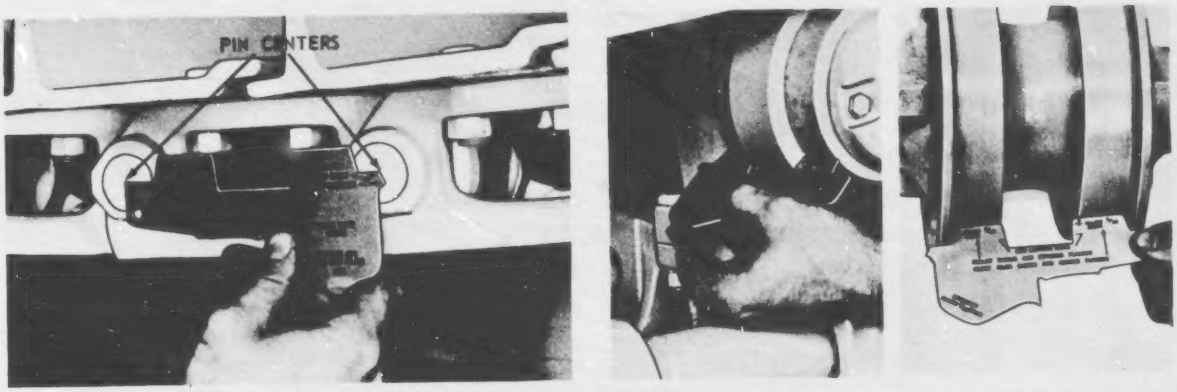
(T-75449)

(6-113) CHECKING SPROCKET TEETH WEAR

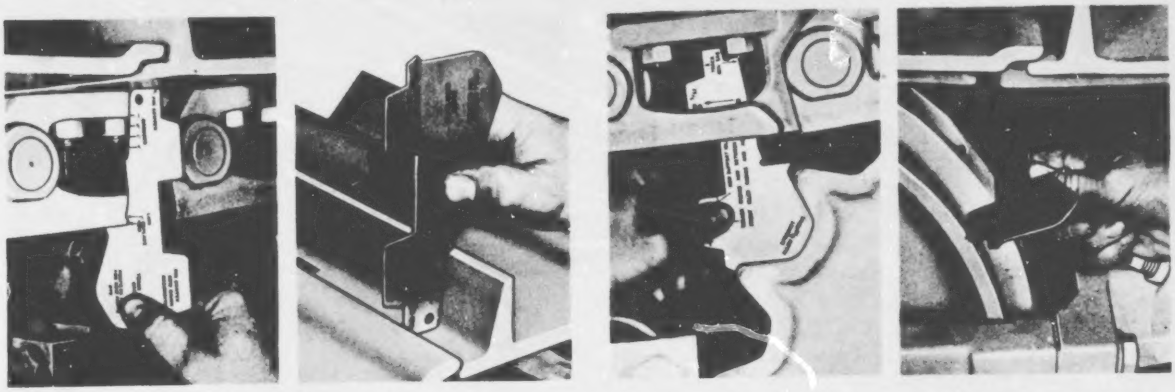
Courtesy of Fiat-Allis Construction Machinery Ltd

Wear Gauges

Gauges for specific machines are available to check the wear on various undercarriage components (Figure 6-114). Wear gauges apply only to the machine they were made for; they can't be used on others.



PIN AND BUSHING WEAR CARRIER ROLLER WEAR TRACK ROLLER WEAR



LINK WEAR SHOE (GROUSER) WEAR DRIVE SPROCKET WEAR FRONT IDLER WEAR

X2668

(6-114) MEASURING TRACK WEAR WITH A SPECIAL WEAR GAUGE

Courtesy of John Deere Ltd

ALIGNMENT

Proper alignment of the roller frames and idlers is essential for long undercarriage life. Improper alignment can cause scalloping of links by the sprocket, excessive flange wear on rollers and idlers, accelerated pin and bushing wear, and difficulty in steering the machine.

Proper alignment basically consists of keeping the sprocket, rollers and idler on each track frame aligned with one another and parallel to the centerline of the tractor. Detected early, misalignment may be corrected with minor adjustments before costly damage has been done. Be observant: look for uneven wear patterns, the signs of misalignment. Be careful about making hasty judgements, though, because wear patterns may look like they are caused by misalignment but are actually caused by stressful working conditions such as side hills.

Following are six alignment checks that can be performed on the tractor in less than 30 minutes.

Track Frame Alignment

1. Measure roller frame toe-in or toe-out.
2. Measure roller frame parallelism.
3. Determine which frame is misaligned.

Idler Alignment

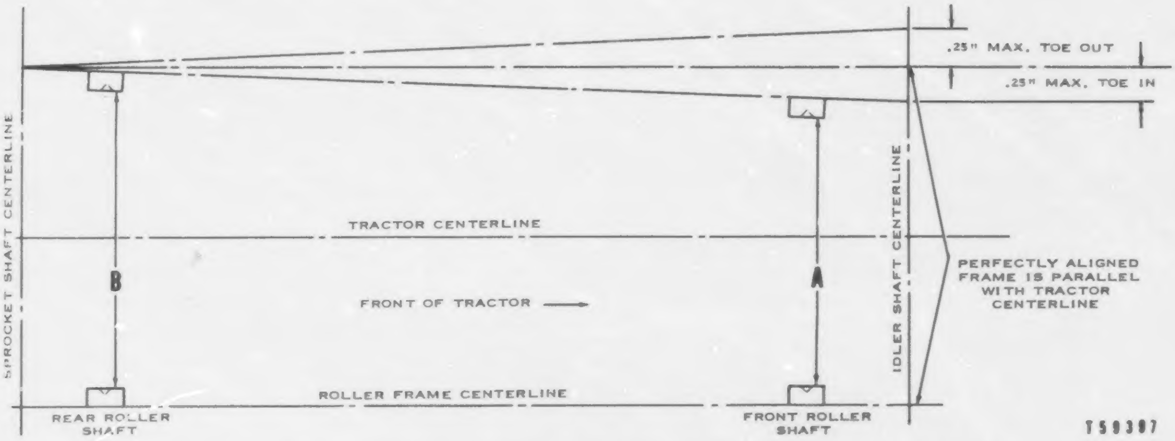
4. Measure idler tilt.
5. Check lateral position of idler.
6. Measure idler toe-in or toe-out.

Move the tractor to firm level ground. Special alignment tool kits are available but if one is not at hand most of the alignment checks can be done with a tape measure and string lines. Always take measurements from a machined surface, one that hasn't been built up with weld.

TRACK FRAME ALIGNMENT

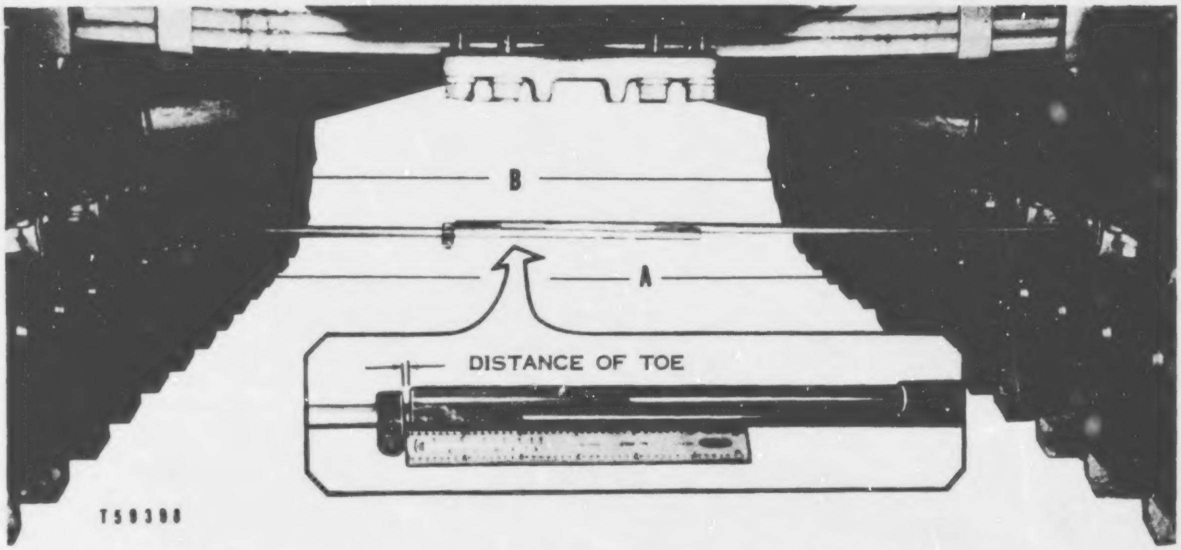
Roller Frame Toe-In Or Toe-Out

Using a tape measure, measure the distance between the rear roller shaft ends, distance B (Figure 6-115). Now measure the distance A between the front roller shafts. For this machine, Length A should be within 1/2 inch of length B. These same measurements can be taken with an alignment kit adjustable bar (Figure 6-116).


.25" MAX. TOE OUT
.25" MAX. TOE IN
SPROCKET SHAFT CENTERLINE
IDLER SHAFT CENTERLINE
TRACTOR CENTERLINE
B
A
FRONT OF TRACTOR
PERFECTLY ALIGNED FRAME IS PARALLEL WITH TRACTOR CENTERLINE
ROLLER FRAME CENTERLINE
REAR ROLLER SHAFT
FRONT ROLLER SHAFT
T59387

THE RECOMMENDED MAXIMUM TOE AT THE IDLER SHAFT CENTERLINE IS .25" (.635 CM.). THE MAXIMUM COMBINED TOE FOR BOTH FRAMES IS .50" (1.27 CM.).

(6-115) Courtesy of Caterpillar Tractor Company


B
A
DISTANCE OF TOE
T59388

MEASURING BETWEEN ROLLER SHAFTS WITH AN ADJUSTABLE BAR AND COLLAR. AN ENLARGED VIEW OF THE COLLAR IS SHOWN IN THE INSET.

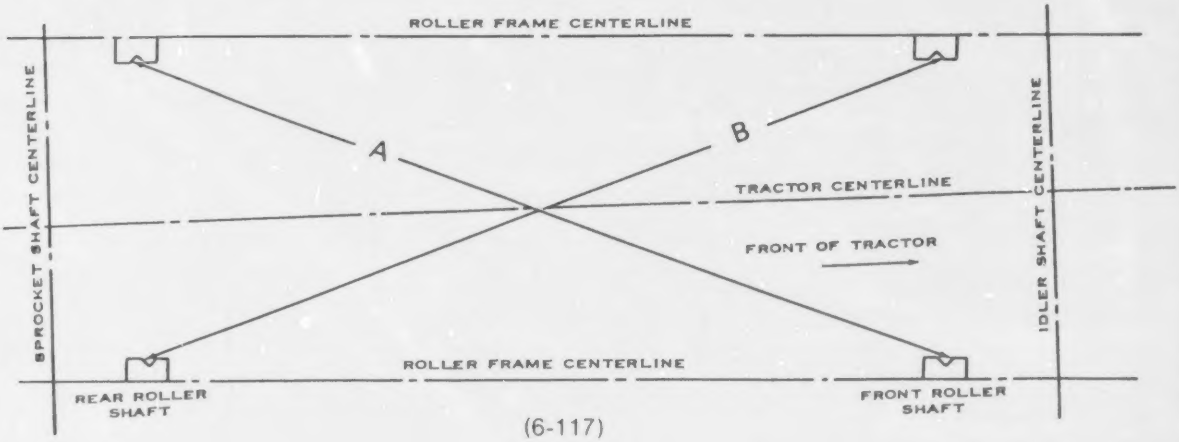
(6-116)

Courtesy of Caterpillar Tractor Company

Roller Frame Parallelism

To further check parallelism of the roller frame, measure the two diagonals from the front roller shaft on one roller frame to the rear roller shaft on the other frame. The two diagonals should be within the acceptable tolerances stated in the service manual.

In the Figure 6-117 the frames are misaligned because the distances A and B are not the same.

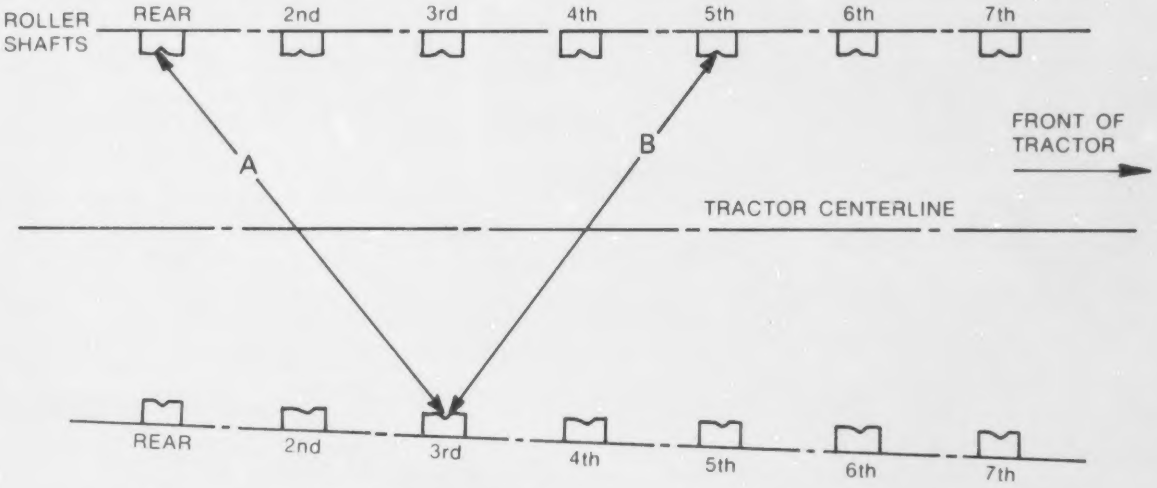

ROLLER FRAME CENTERLINE
SPROCKET SHAFT CENTERLINE
A
B
IDLER SHAFT CENTERLINE
TRACTOR CENTERLINE
FRONT OF TRACTOR
ROLLER FRAME CENTERLINE
REAR ROLLER SHAFT
FRONT ROLLER SHAFT

(6-117)

Which Frame Is Misaligned?

In check two the frames were found to be misaligned. Check three will show which frame is misaligned or will show if both are misaligned.

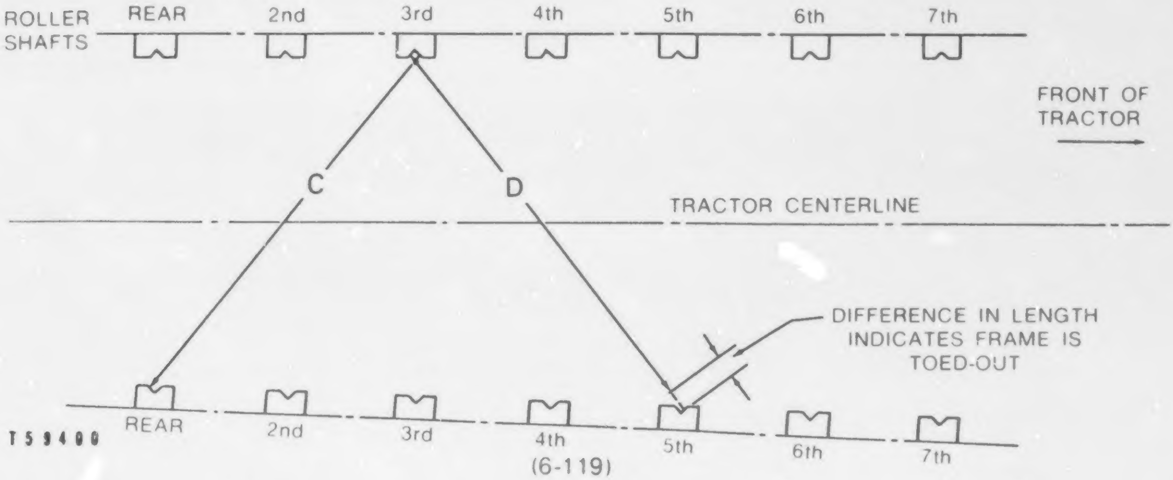
(a) Two measurements are made with a tape, distance A and distance B in Figure 6-118. In this case A and B are the same, and therefore the track frame represented by the top line is aligned.


ROLLER SHAFTS
REAR
2nd
3rd
4th
5th
6th
7th
A
B
FRONT OF TRACTOR
TRACTOR CENTERLINE
REAR
2nd
3rd
4th
5th
6th
7th

(6-118) METHOD OF DETERMINING RELATIVE POSITION OF ROLLER FRAMES

(b) Now two more measurements are taken, distance C and distance D in Figure 6-119. Since D is longer than C the track frame represented by the bottom line is toed-out. If D happened to be shorter than C, then the frame would be toed-in.

If the roller frames are misaligned beyond acceptable tolerances, the track frame would have to be removed to correct the alignment.

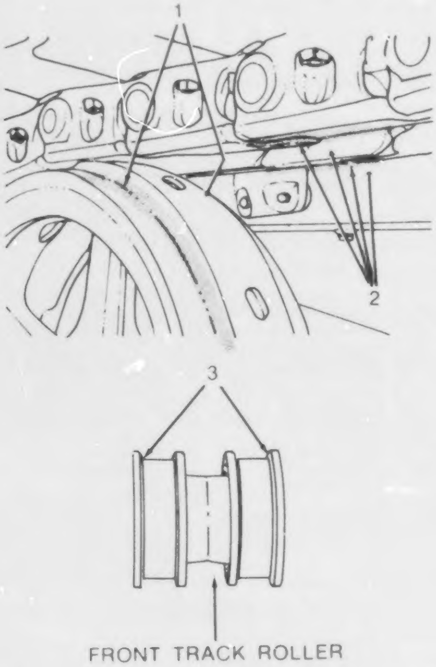

ROLLER SHAFTS
REAR
2nd
3rd
4th
5th
6th
7th
FRONT OF TRACTOR
C
D
TRACTOR CENTERLINE
DIFFERENCE IN LENGTH INDICATES FRAME IS TOED-OUT
REAR
2nd
3rd
4th
5th
6th
7th

T59400

(6-119)

IDLER ALIGNMENT

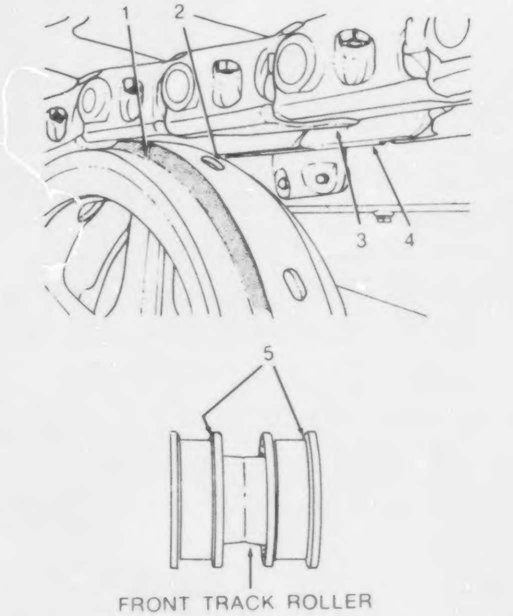
Idler misalignment is one of the most common undercarriage problems. Located at the front of the machine, the idler takes the brunt of the shocks hitting the front of the track. Figure 6-120 shows wear patterns of aligned and misaligned idlers. To check idler alignment, measurement must be taken for ideal tilt, lateral position and toe-in and toe-out.



1 Light Even Contact On Each Side Of Idler Flange
2 Light Even Contact On Both Sides Of Side Links
3 Light Even Contact On All Flanges Of Track Rollers

(6-120) WEAR PATTERN-TRACK AND IDLER PROPERLY ALIGNED

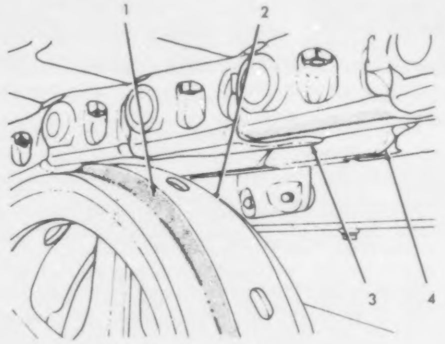
Courtesy of Fiat-Allis Construction Machinery Inc



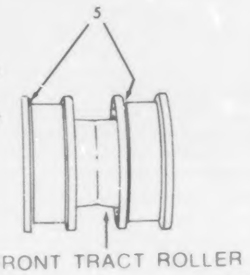
1 **Heavy Contact (Cutting If Toe-In Is 1/4" or More) On Idler Outer Flange**
2 Moderate Contact On Idler Inner Flange
3 Heavy Contact (Cutting If Toe-In Is 1/4" Or More) On Inner Side Of Outer Side Links
4 Heavy Contact On Outer Side Of Inner Side Links
5 Heavy Contact On Inner Flanges

(6-120) WEAR PATTERN OF TOED-IN IDLER

Courtesy of Fiat-Allis Construction Machinery Inc



1. Heavy Contact On Idler Outer Flange
2. Light To No Contact On Idler Inner Flange
3. Heavy Contact On Inner Side Of Outer Track Link
4. Light To No Contact On Inner Side Of Inner Track Link
5. More Contact On Flanges

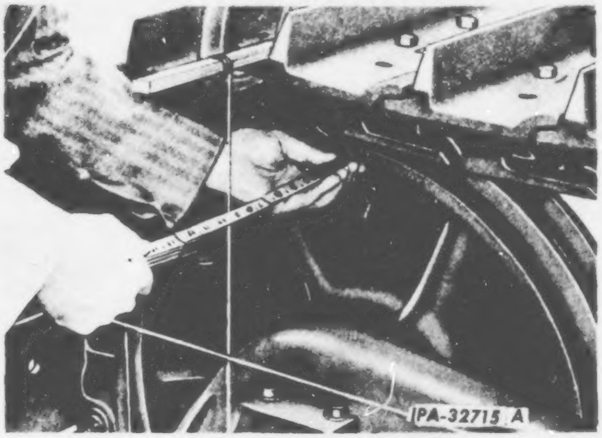


(6-120) WEAR PATTERN—IDLER OFF-CENTER TOWARD OUTSIDE

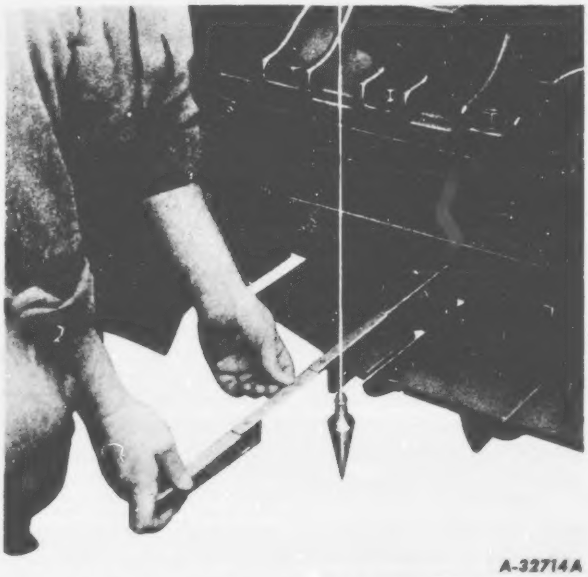
Courtesy of Fiat-Allis Construction Machinery Inc

Idler Tilt

To check idler vertical alignment or tilt, a plumbed line is dropped from the outer edge of a track shoe and a measurement is taken at the top and at the bottom of the idler (Figure 6-121). If the two measurements are not the same, the idler is tilted.

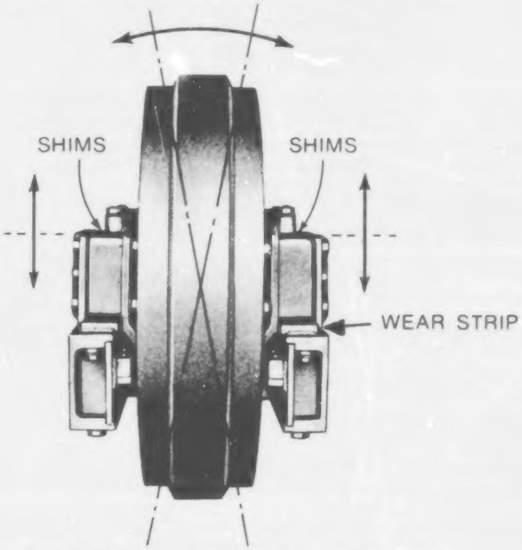


(6-121) VERTICAL ALIGNMENT CHECK AT TOP OF FRONT IDLER
Courtesy of International Harvester



(6-121) VERTICAL ALIGNMENT CHECK AT BOTTOM OF FRONT IDLER
Courtesy of International Harvester

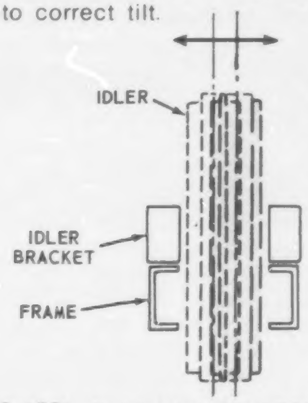
In some cases tilt can be corrected by moving shims from one side to the other (Figure 6-122). In other cases tilt will be caused by wear on the bearing supports or track frame rails. To correct this more serious problem the idler will have to be removed and wear strips and/or bearing support brackets replaced.



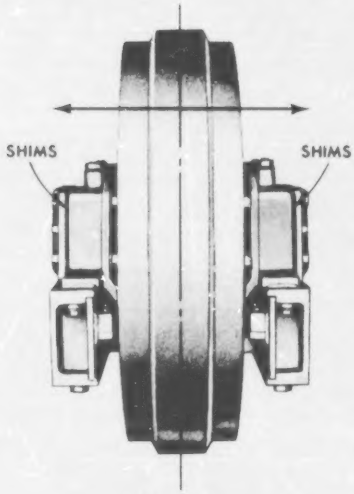
(6-122) IDLER ADJUSTMENTS
Courtesy of Caterpillar Tractor Co

Idler Lateral Position

The idler can get shifted sideways (Figure 6-123). A visual check lining up the center flange of the idler with the first track roller will tell if the idler lateral position is out. Also, a wear pattern on a side of the idler center flange, caused by a crowding of the links, will indicate incorrect lateral position. To correct the lateral position shims are moved from one side of the ider to the other (Figure 6-124). Note that this set of shims is different than that used to correct tilt.



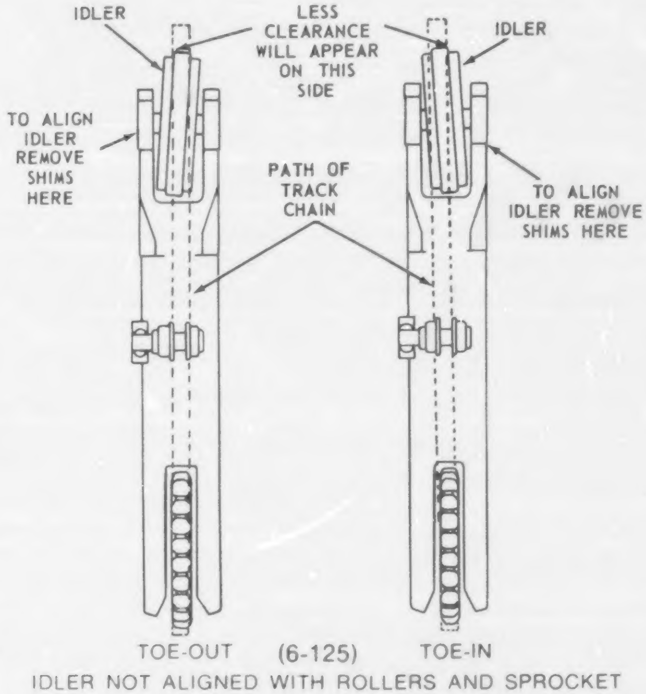
(6-123) IDLER NOT CENTERED
Courtesy of John Deere Ltd


SHIMS
SHIMS

(6-124)
Courtesy of Caterpillar Tractor Co

Idler Toe-In and Toe-Out

Measure from the inside front face of one idler to the inside front face of the other idler. Now measure from the back inside face of one idler to the back inside face of the other idler. A difference of measurement will indicate a toe-in or toe-out problem (Figure 6-125). To correct toe-in or toe-out, the idler has to be removed and any worn wear strips or bearing support brackets must be replaced.


IDLER
LESS CLEARANCE WILL APPEAR ON THIS SIDE
IDLER
TO ALIGN IDLER REMOVE SHIMS HERE
PATH OF TRACK CHAIN
TO ALIGN IDLER REMOVE SHIMS HERE

TOE-OUT (6-125) TOE-IN
IDLER NOT ALIGNED WITH ROLLERS AND SPROCKET
Courtesy of John Deere Ltd

ALIGNMENT OF EXCAVATORS, SHOVEL AND CRANE TRACK FRAMES

Track frames for excavators, shovels and cranes are usually an integral part of the truck frame or car body, and are therefore not prone to the same misalignment problems as crawler dozers and loaders. However, the components must still be mounted straight and the front idler must be kept in alignment so the track will lay straight with a minimum of wear on the other components.

QUESTIONS — UNDERCARRIAGE SCHEDULED MAINTENANCE

1. List four stress factors that can cause accelerated undercarriage wear.
2. Name the two types of wear that occur on the track pins and bushings, and briefly explain the damaging effects that occur as the wear increases.
3. What are the advantages of sealed and lubricated tracks over sealed tracks?
4. What will a Percentage Worn Chart tell you?
5. Refer to the Percentage Worn Chart given in this section to answer these questions.
   (a) If a track roller on a D9 was calipered and found to be 10.1 inch, what would be its percentage worn?
   (b) If the links on a D8 (158839-40) measured 4.3 inches, should the links be rebuilt?
6. Briefly explain how to measure pin and bushing wear.
7. What does turning pins and bushings achieve?
8. If a severely worn sprocket is used with a new track chain, would it cause problems? Briefly explain.
9. Track alignment involves keeping the ____________, ____________, and ____________ aligned with one another and parallel to the centerline of the tractor.
10. What is an obvious sign of misalignment?
11. What is the most common cause of idler misalignment?
12. In what three ways may an idler be misaligned?
13. Briefly explain how to tell if two track frames are parallel.

SERVICE REPAIR ON TRACK MACHINE UNDERCARRIAGE

REMOVAL AND INSTALLATION OF TRACKS

Removal of a crawler machine undercarriage, although not highly technical, is a major job in that you are removing large, heavy pieces of equipment. Suitable jacking and lifting equipment is required, and solid blocking is necessary to support the machine. Since working with heavy machinery is always potentially dangerous, safety must be foremost in mind when removing or installing undercarriage components.

A track machine's service manual has step-by-step procedures showing how to remove or install the tracks, track frames and track frame components. Until familiar with a machine, you should have the manual in front of you and follow the steps. When the job becomes routine the manual will no longer be as important, but you will always know where to find any procedure you are uncertain of.

The relationship between this book and service manuals should be pointed out here. This book is not a substitute for service manuals; it will not present detailed, step-by-step service and repair procedures. The material in these pages is intended to supplement service manuals, to indicate what service repair is done on a component, to summarize service procedures, to stress a certain procedure or a safety precaution, and generally to provide helpful practical service tips and information not usually found in the manuals.

SUMMARY OF STEPS TO REMOVE AND INSTALL TRACKS

1. Slacken the track.
2. Position the master pin or master link for convenient removal.
3. Remove the master pin or disconnect the master link.
4. Remove the track and roll and tie it for storage or shipping.
5. Install the track.
6. Adjust the track.

Slacken The Track

Slackening and tightening the tracks is covered earlier in the discussion on track tension in Daily Routine Maintenance.

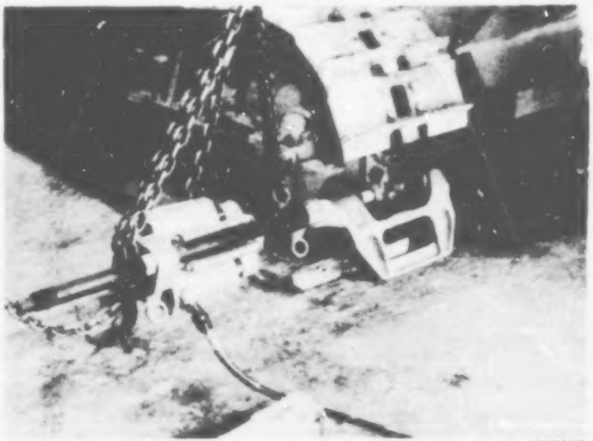
Positioning The Master Pin Or Master Link For Removal

The position in which the master pin or link is put prior to removal is largely a matter of preference. Depending on what service is to be done on the machine, one position may be more advantageous than another. For example, if work is to be done on the final drive a position toward the rear would be more convenient.

Removing The Master Pin

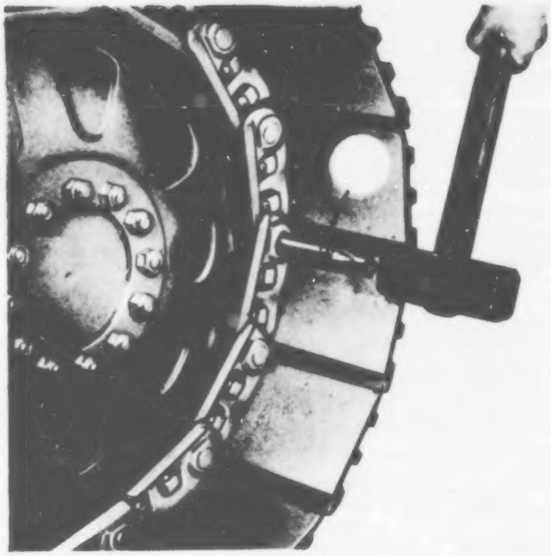
Safety Precaution — to prevent injury to your feet, before removing the pin place a block in front of the track to support the track when it is released. Always keep hands and feet clear when separating or joining tracks.

The way master pins are held in position varies from machine to machine, but the method of removal is similar. A hydraulic pin press (Figure 6-126) is the accepted tool for removing pins. When a press is not available, a large hammer and drift may do the job (Figure 6-127). Master pins on large machines however, can be very difficult to remove with a hammer and drift. **Caution:** when hammering out a pin use eye protection because of the danger of flying metal chips.



(6-126)

Courtesy of J.I. Case



(6-127)

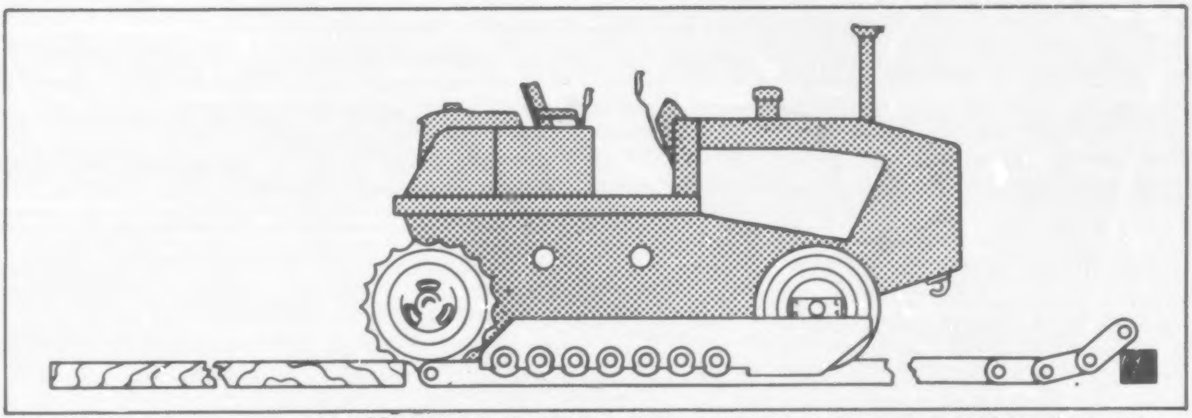
Courtesy of Massey Ferguson Inc

Remove The Track

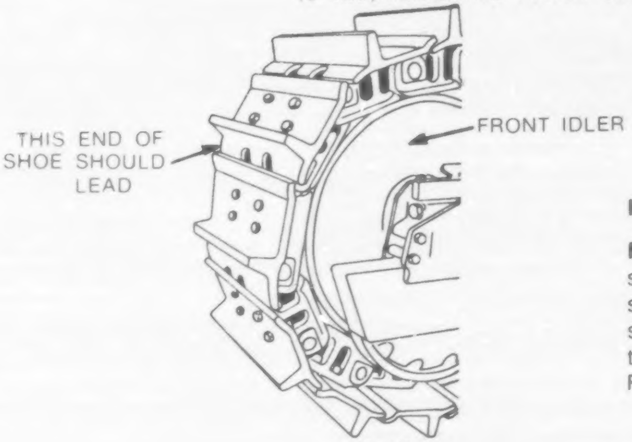
1. Elevating the machine (in the shop): with the machine raised a few inches use an overhead crane or other suitable lifting device to lift the upper part of the track and lay it out on the floor. The track can then be pulled clear of the machine with a fork lift or crane truck, and rolled and tied for storage or shipping (Figure 6-128).

(6-128)

2. Without elevating the machine: once the track has been separated at the front of the machine start the machine and back it up until it reaches the end of the track. Place at the end of the track, a plank that is approximately the same width and height as the track and about the same length as the machine. Back the machine onto the plank (Figure 6-129).



(6-129) REMOVING TRACK CHAIN Courtesy of Terex General Motors Corporation



(6-130)

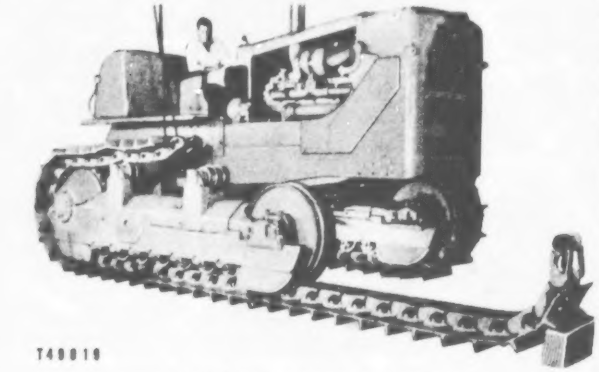
Caution: When using the plank method to remove both tracks, be sure the machine is on level ground. Should it be on an incline, the machine could roll because there is no way of braking it once it is off the tracks.

Installing The Track

Note: There is a right and wrong way to install tracks. The grouser bar is closer to one side of the shoe than the other and it is this side of the shoe that should lead the track towards the front of the machine, as seen in Figure 6-130.

1. Installing tracks on large machines

Figure 6-130 shows a track being installed on a large tractor. The top of the track is supported by an overhead crane while the machine is driven forward to the point of recoupling. A come-along can be used, especially on big machines, to draw the two ends of the track together and make it easier to install the master pin. Figure 6-131 illustrates installing tracks on a large shovel.

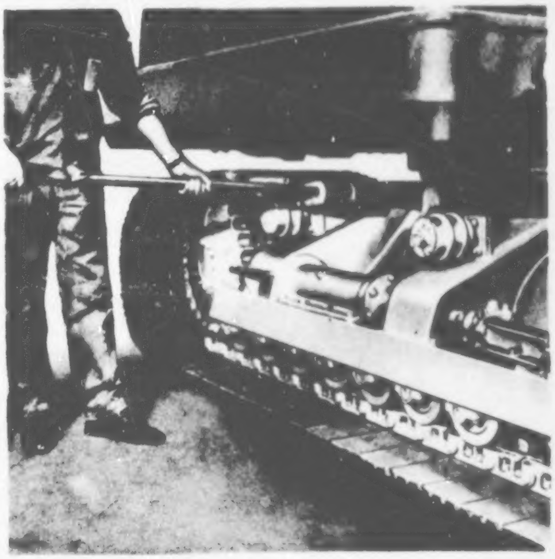


(6-130) INSTALLING TRACK

Courtesy of Caterpillar Tractor Co

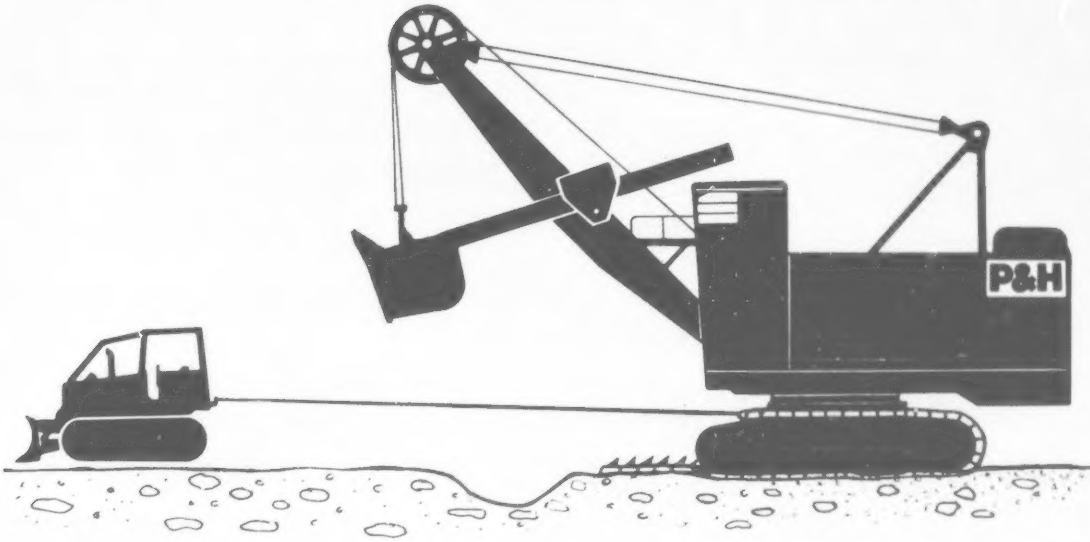
2. Installing tracks on a smaller machine.

Figure 6-132 shows a track being installed on an excavator. The mechanic guides the track over the idlers while the machine is driven forward. This practice is suitable for smaller and lighter tracks.



(6-132)

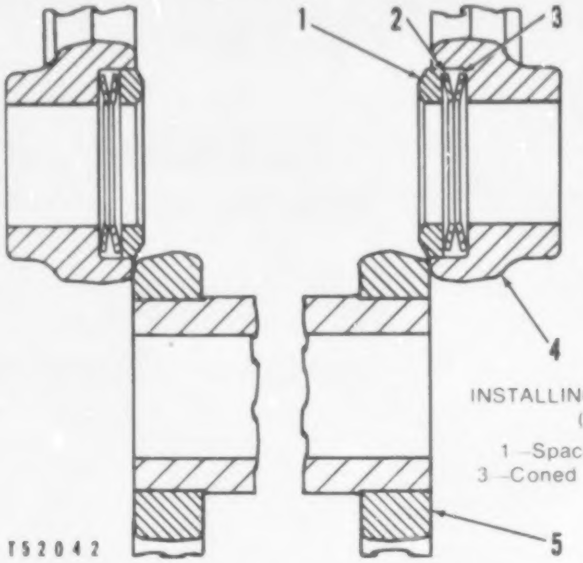
Courtesy of Massey Ferguson Inc

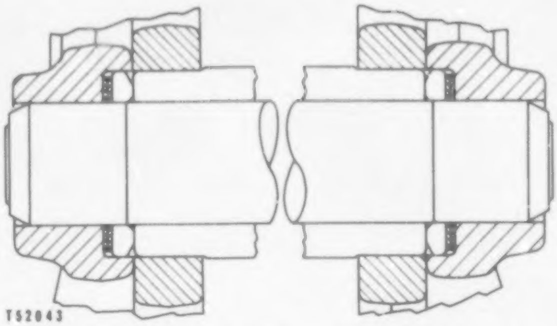


(6-131) Courtesy of Harnishfeger Corporation P&H

Joining the Track

When coupling the track be sure the seals are in place, the pin is inserted correctly (Figure 6-133), and the pin is locked by whatever means the manufacturer suggests — press fit, lock ring, pin or bolt.





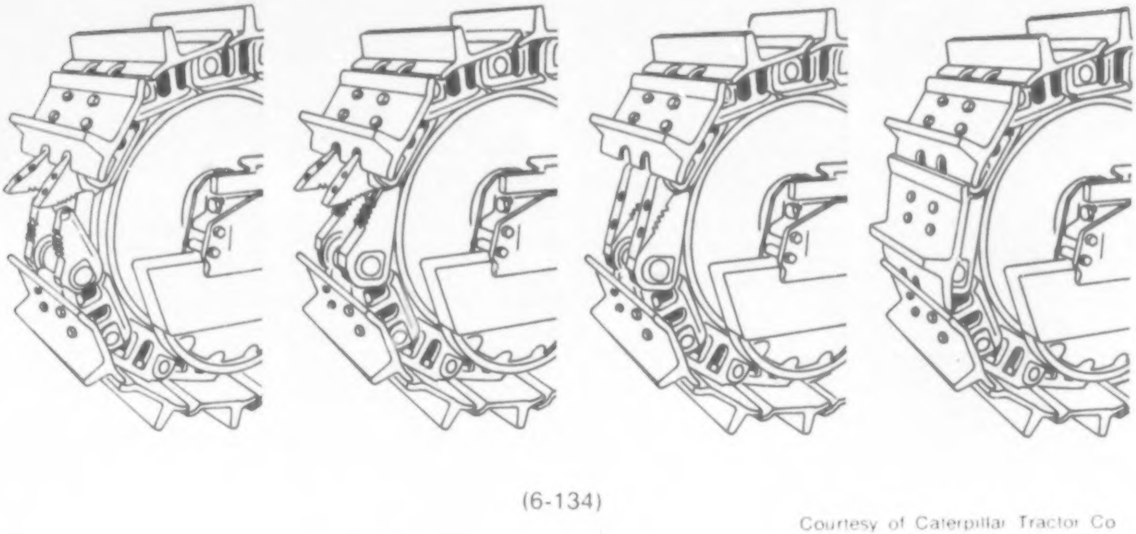
MASTER PIN CORRECTLY INSTALLED
(Later Tracks Illustrated)

INSTALLING SEAL WASHERS AND SPACER
(Later Tracks Illustrated)
1—Spacer. 2—Coned disc seal washer.
3—Coned disc seal washer. 4—Master link.
5—Track link.

Courtesy of Caterpillar Tractor Co

(6-133)

Figure 6-134 shows the assembly sequence of a track that uses a master link. When the split links are mated, a track shoe is put on top and four bolts inserted.



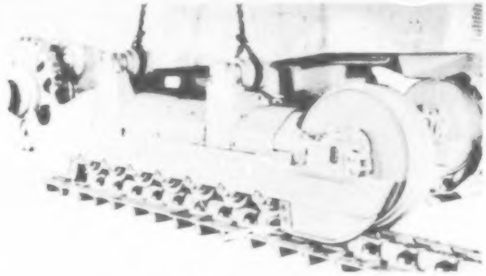
(6-134)

Courtesy of Caterpillar Tractor Co

REMOVING THE TRACK FRAME

The machine must be jacked and blocked to remove the track frame. As with tracks, there is more than one way to remove track frames. The size of the machine, the availability of lifting equipment, and the machine's location are all factors influencing the removal of the track frame. In terms of safety on this job, it's enough to say that a track frame of a D9 weighs about four and a half tons.

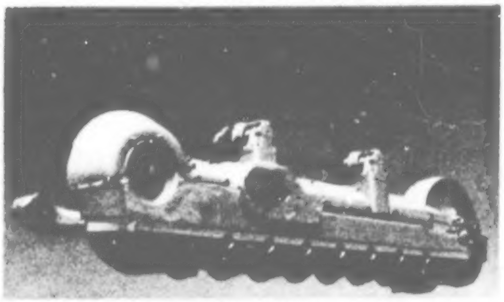
One way to remove the track frames in a shop is with an overhead crane or a chain block. The slings are placed around the carrier rollers which give a fairly good balance point (Figure 6-135). Once the frame has been disconnected at the outboard bearing and at the diagonal brace, the frame can be pried free of the equalizer bar and lifted clear (Figure 6-136). When overhead lifting equipment is not available, mobile machines like a crane truck or fork lift can be used.



(6-135)

REMOVING THE TRACK ROLLER FRAME

Courtesy of Caterpillar Tractor Co



(6-136)

Courtesy of Caterpillar Tractor Co

If no lifting equipment is available, as may happen in the field, it is possible to remove the track frame in the following way:

1. Leave the track under the track frame. Jack and safely block the machine high enough so that the sprocket clears the track chain.
2. Disconnect the track frame at the diagonal brace and outboard bearing or at the pivot point if the frame is mounted forward.
3. Using a crowbar or suitable lever, pry the front of the frame out so that it clears the equalizer bar. Tilt the frame inwards so that the diagonal brace clears the under side of the machine and roll the track frame forward on the track.

Removing the frame as above may sound easy but in practise it can be quite difficult, especially on larger machines. Precautions should be taken with hands and feet when doing this job.

Removing Track Frame Components

If cleaning equipment is available (steam cleaner or high pressure washer) clean the frame before removing components.

Removing most of the components from the track frame is a relatively straightforward job. Refer to the service manual, though, before removing the recoil mechanism and hydraulic adjuster, because the method of removing them will vary from machine to machine.

After removing the components, the track frame should be checked thoroughly for cracks, twists, bends and any other evidence of damage and wear. Minor repairs will include:

1. Removing any broken bolts.
2. Tapping out all threaded holes and repairing any worn holes.
3. Welding any cracks and worn areas. (This will usually be done by a journeyperson.)
4. Sanding all bolting surfaces with a disc sander and a coarse disc to remove paint and rust build-up. Sanding will ensure a good metal to metal contact on assembly and prevent components loosening when back in service.

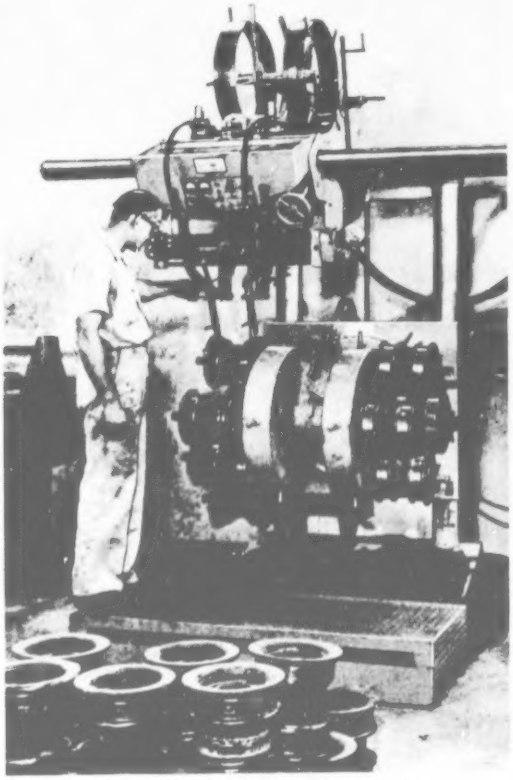
Should major repairs be necessary to the frames such as repairing bends, twists or doing extensive welding, the frames will generally be shipped to a shop equipped for this kind of work. Special jigs and presses are required and are not normally found in smaller shops.

SHOULD TRACK FRAME COMPONENTS BE REPAIRED OR REPLACED?

Repairing or replacing track frame components is a controversial subject with opposing views held on what is the best policy to follow. The decision whether to repair or to replace track frame components depends on a number of factors. Some of these are:

1. **Working Conditions** — Some abrasive materials that a machine may work in will cause accelerated wear on parts and make repair impractical.
2. **Economics** — the cost of parts, labor and downtime must be balanced against the cost of running the undercarriage to destruction. Some companies feel production is more important and they will run the undercarriage until it stops. Other companies consider it a proven fact that a good preventive maintenance program combined with repair pays off.
3. **Parts Availability** — demands world-wide for heavy equipment steel parts have in the past created a parts shortage. If a part is difficult to get, it is more likely to be maintained and repaired.

A discussion follows on what types of repairs are done to the different undercarriage parts.



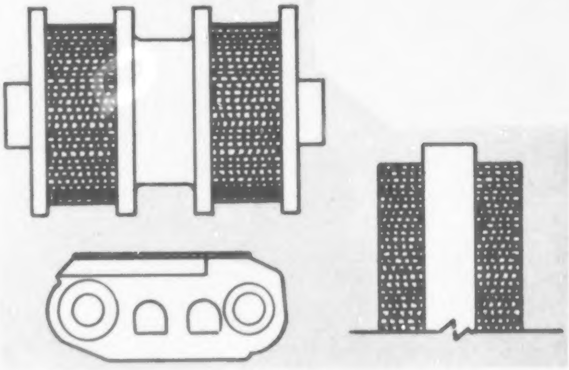
(6-137) WELDING MACHINE

Courtesy of Caterpillar Tractor Co.

UNDERCARRIAGE REPAIRS

Weld Build Up To Restore Running Surfaces

Worn running surfaces and flanges of track rollers, carrier rollers and front idlers can be built up with weld to their original diameters. The welding is done by a machine which deposits a much more uniform surface than could be done by hand. Building up worn tread surface with weld can extend the life of the part 70 to 90 percent (Figure 6-137 and 138).



(6-138)
ROLLER, IDLER AND LINK
WITH BUILT UP TREAD SURFACE

PARTS WITH TREAD SURFACES
BUILT UP

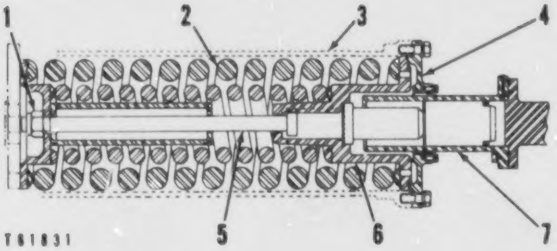
Courtesy of Terex, General Motors Corportion

Recoil Mechanisms

The recoil mechanism generally requires little repair. It is usually removed from the track frame, visually inspected and reinstalled. If any damaged or broken parts are found, though, they should be replaced. Each type of recoil mechanism — coil spring, disc and conical spring, or gas charged cylinder — has specific disassembly and reassembly steps and safety precautions to be followed. Always refer to a service manual before attempting to work on a recoil unit.

Coil Spring Recoil Mechanism

When assembled, the springs are compressed to a specific length and held by a through bolt before being installed in the track frame. Once installed, the nut (No. 1 in Figure 6-139) on the tension bolt is backed off and locked, and the spring is held by stops on the frame. Attempting to remove the recoil mechanism without retightening the nut could cause injury; when the front stop bolts are removed the extreme force of the spring could shear the last few threads on the through bolt and the mechanism would fly apart.



RECOIL SPRING ASSEMBLY
1–Nut. 2–Recoil spring. 3–Housing. 4–Front cover. 5–Recoil spring bolt. 6–Front pilot. 7–Track adjusting mechanism.

(6-139)

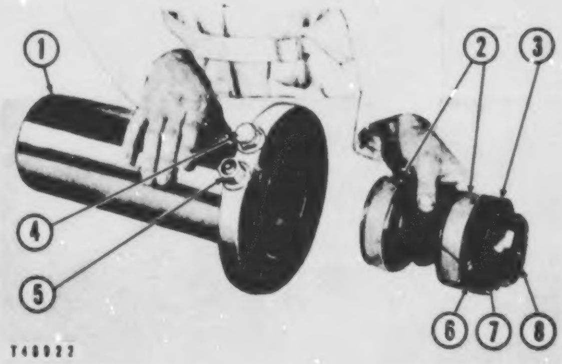
Courtesy of Caterpillar Tractor Co

Conical Spring Recoil Mechanism

Conical springs require no maintenance and should present no problems in removal and installation. Disassembling the spring unit once it is out of the track frame requires a hydraulic press because it is held together under tension.

Hydraulic Track Adjuster

The hydraulic track adjuster is an integral part of the coil spring and conical spring recoil mechanism. To repair the adjuster cylinder (Figure 6-140), treat it as any hydraulic cylinder: replace seals, smooth burrs or scores, and replace any worn or damaged parts. On reassembly make sure the parts are clean and lubricated.



1–Cylinder. 2–Rings. 3–Packing. 4–Relief valve. 5–Ball check assembly. 6–Washer. 7–Snap ring. 8–Piston.

(6-140)

Courtesy of Caterpillar Tractor Co.

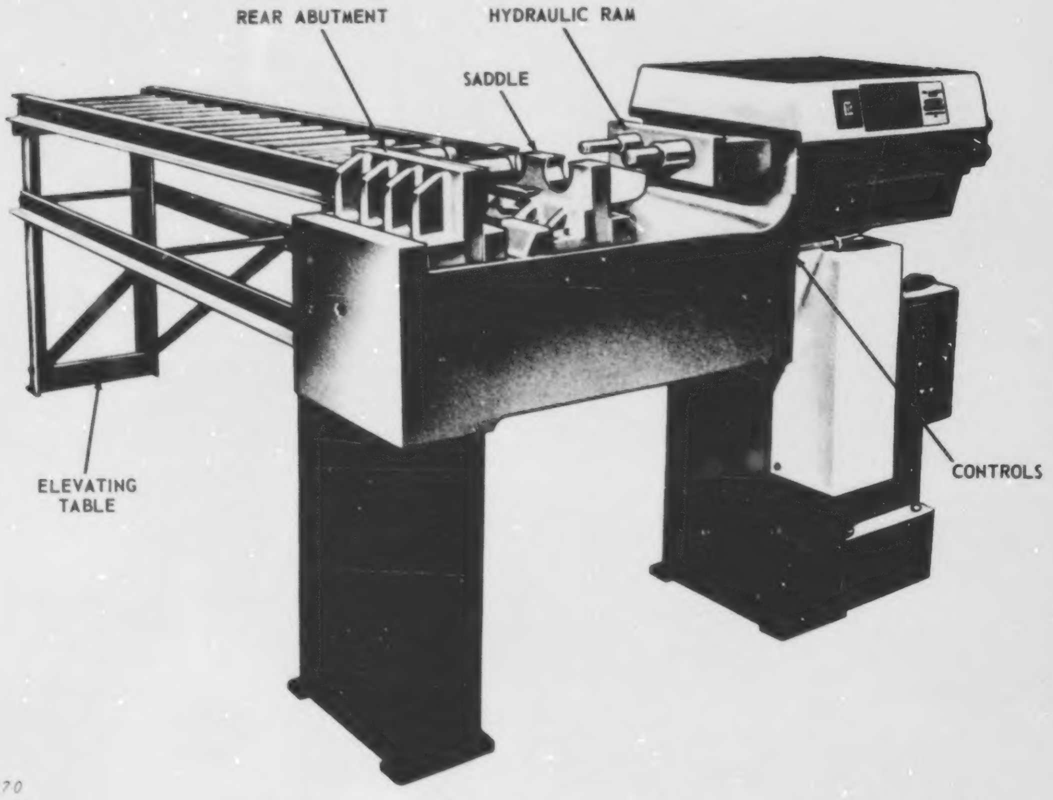
Gas Charged Cylinder

The gas charged cylinder is the recoil mechanism and the hydraulic track adjuster all in one. Since the cylinder is under high pressure, caution must be used when working on it. To remove the cylinder from the track frame, grease is pumped into the adjuster cavity to retract the piston. The cylinder is then disconnected and lifted out. Referring to the service manual, grease is bled from the cylinder and the gas charge is exhausted. To repair the gas charged cylinder, treat it as any hydraulic cylinder.

Turning Pins and Bushings

Sealed Tracks

To turn pins and bushings on sealed tracks, the track must be removed and taken to a shop equipped with a track press (Figure 6-141). Each pin and bushing is pressed out, one at a time, rotated 180 degrees and pressed back into the links. New sealing washers are installed during the process.



(6-141) TRACK PRESS DESIGNED TO DISASSEMBLE TRACKS

Courtesy of John Deere Ltd.

Lubricated Tracks

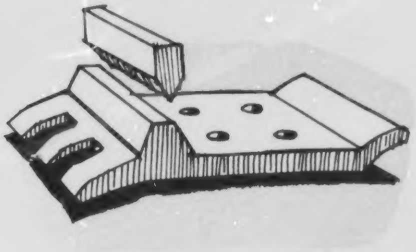
Bushings on sealed and lubricated tracks can be turned if their external wear becomes excessive. The pins, though, are not turned because if they were the lube hole would be pointing up and could not feed oil to the pin and bushing contact surface area (see Figure 6-64). Anyway, the pins don't need to be turned because there is very little wear on them.

Links

Links can have their tread surface built up with weld. Whether it's practical or economical to do so would have to be decided in the individual case. Generally speaking, a set of links will last one turning of the pins and bushings and then will have to be replaced.

Track Shoes

Worn track shoes can be reconditioned by welding on new grouser bars (Figure 6-142). A shoe's beam strength comes from grouser height, and so welding must be done before the grouser becomes so worn that the shoe bends. Worn charts will give the point at which the shoe should be rebuilt.



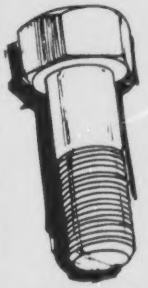
(6-142)

Courtesy of Caterpillar Tractor Co

Another repair that is made to standard shoes is to deposit a hard surface weld on top of the grouser bar. The grouser should be worn about 1/2 inch before being surfaced because the heat from the weld will destroy the original heat treatment.

Track shoes must be kept tight to prevent damage to the shoes and links. Before installing new shoes on (a new or used) track chain be sure to sand all painted or rusted surfaces. Paint or rust between the two surfaces will usually cause the shoe to loosen in service. Shoe bolts should be tightened to service manual specifications with a torque wrench. An example of torque pressures is given in Figure 6-143.

PROPER TORQUE FOR TRACK HARDWARE



BOLT DIAMETER (INCHES)	THREADS PER INCH	TORQUE POUND-FOOT
9/16	18	65 ± 15 plus 1/3 extra turn
5/8	18	130 ± 30 plus 1/3 extra turn
3/4	16	220 ± 40 plus 1/3 extra turn
7/8	14	250 ± 50 plus 1/3 extra turn
1	14	250 ± 50 plus 1/3 extra turn

(6-143) Courtesy of Caterpillar Tractor Co

Shovel and Crane Tracks

Because shovels and cranes move slowly and most of their work is done standing still, they are not subjected to the same kind of abuse that dozers and loaders are. However, they do have some operating stresses. The machines are very heavy and back and forth movements as the machines dig and load or lift cause some wear on the shoes, rollers, idlers and drive tumblers. Repairs to shovel and crane tracks are fairly limited. Some build-up or hard surfacing is welded to the inner side of the shoe to extend track life. Pins are replaced when they are broken or when they become extremely worn. Shoes are replaced when cracked or broken.

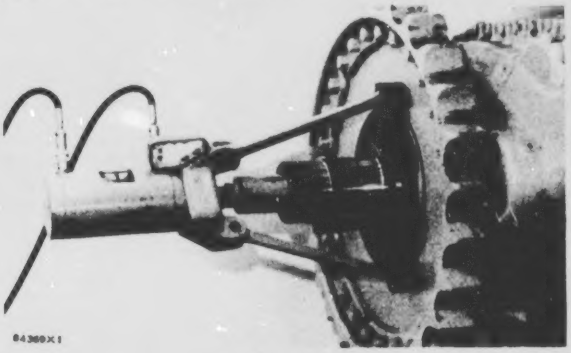
Sprockets

Sprocket Removal

When the tracks and track frame are removed from the machine, the sprocket remains attached. The method of removing a sprocket varies because each type may be attached to the final drive in a different way. (See the service manual for removal of individual sprockets.) The most difficult sprockets to remove are those that are pressed onto splined final drive hubs. To remove these sprockets requires a portable hydraulic press capable of pulling or pushing up to 100 tons. Such presses can be rented if a shop doesn't have one. When using a hydraulic press, it is important to have correct adapters and to push in a place that won't damage the final drive.

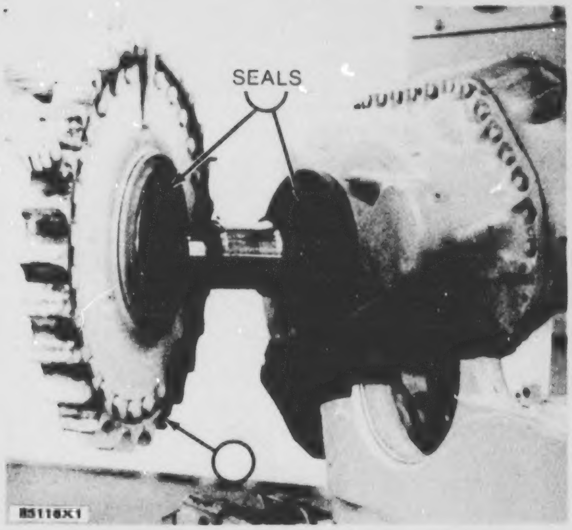
Caution: Before removing the sprocket, back off the sprocket retaining nut only far enough to allow 1/4 inch between the sprocket face and the nut. So positioned, the nut will prevent all the parts flying onto the floor when the sprocket is pulled loose.

Figure 6-144 shows an assembled press ready to pull a sprocket. Note that the sleeve presses against the end of the final drive gear hub and not against the dead axle. Figure 6-145 shows the sprocket removed.



(6-144)

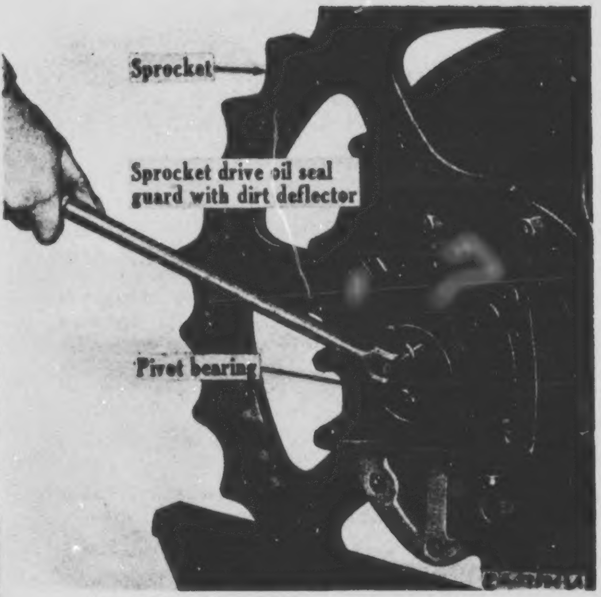
Courtesy of Caterpillar Tractor Co.


SEALS
85116X1

(6-145)

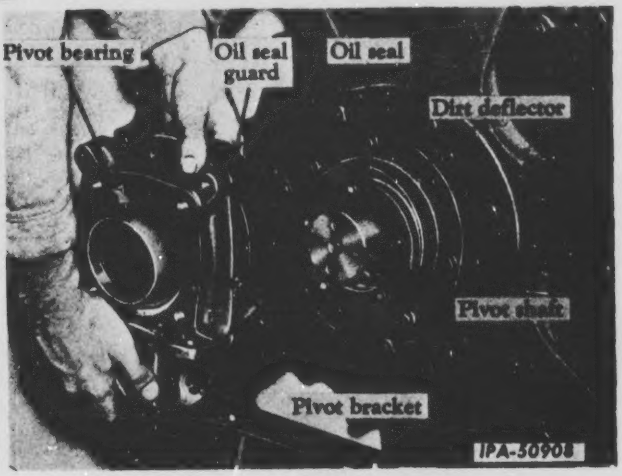
Courtesy of Caterpillar Tractor Co.

Figure 6-145 shows a spoke sprocket being removed from a small tractor having a pivot bearing.


Sprocket
Sprocket drive oil seal guard with dirt deflector
Pivot bearing

(6-146) REMOVING PIVOT BEARING

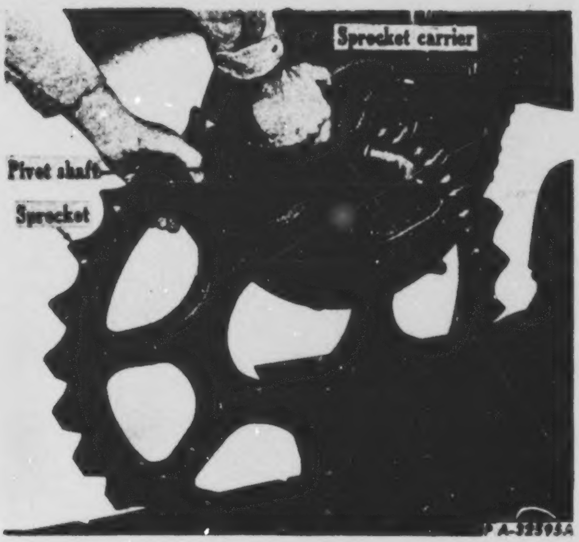
Courtesy of International Harvester


Pivot bearing
Oil seal guard
Oil seal
Dirt deflector
Pivot shaft
Pivot bracket
IPA-50908

(6-146)

REMOVING PIVOT BRACKET ASSEMBLY

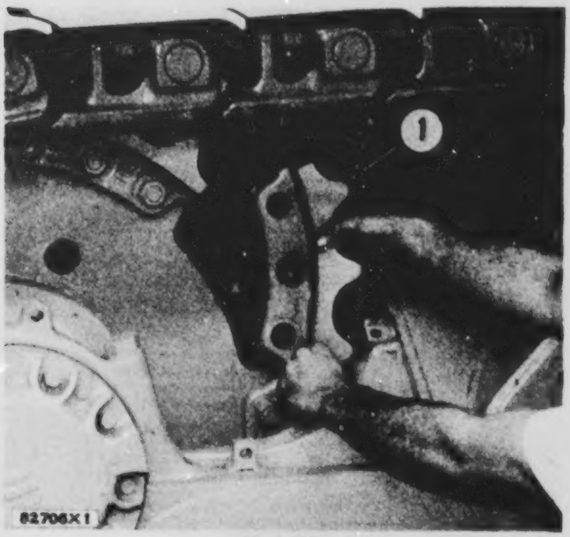
Courtesy of International Harvester



(6-146) REMOVING SPROCKET

Courtesy of International Harvester

Figure 6-147 shows a sprocket segment being removed. The segment can be taken off without removing the track. When installing new segments be sure the bolting surfaces are clean and free of dirt, paint or rust, and carefully torque all bolts in a sequence to avoid distortion of the drive disc.

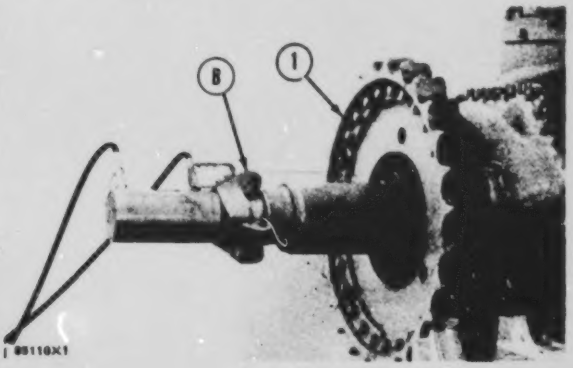


(6-147)

Courtesy of Caterpillar Tractor Co.

Sprocket Installation

Consulting the service manual, reverse the removal procedures. Be sure everything is clean, the seals are in good condition and in place, and the splines are free of burrs. Press on the sprocket (Figure 6-148), applying the specified pressure. Sixty-five tons or more may be needed. Tighten the retaining nut and install the lock.



(6-148)

Courtesy of Caterpillar Tractor Co.

Sprocket and Drive Tumbler Repair

In the past new rims were welded to some of the more expensive spoke sprockets and sprocket teeth were built up, but today very little sprocket repair is done. The hunting tooth design, precision cut teeth, and now sealed and lubricated tracks have greatly extended sprocket life.

One service that is done to sprockets is swapping them. If the forward drive side sprocket wear is more severe than the reverse drive side, the sprockets can be interchanged.

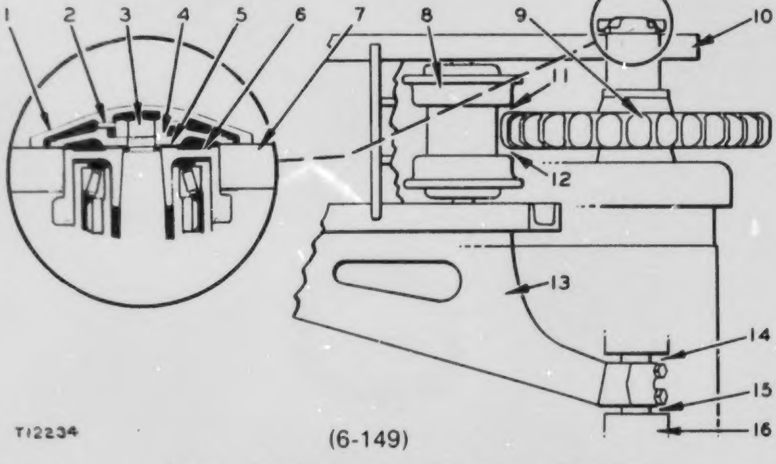
Drive tumblers for shovels and cranes can be repaired with welding build up. Shovel tracks are not as precisely made as dozer tracks and can tolerate this type of repair.

INSTALLING COMPONENTS TO THE TRACK FRAME

Once the frame and components are repaired or new parts are obtained, reinstall all parts in the reverse order in which they were removed. Follow procedures given in the service manual. Some points to observe are:

1. Mount single and double flange rollers alternately on the frame ending at the rear with a single flange. Be sure all rollers are mounted so that the lube fill plug faces the outside.

2. Be sure all end caps are torqued to specifications.
3. Install the recoil — track adjuster assembly. If it is the type that is submersed in oil, refill it to the correct level.
4. If the idler is adjustable, be sure it is installed to the required low or high working height. Most important, align the idler once installed because idler misalignment can cause rapid wear on all the other parts.
5. Be sure to line up carrier rollers with the front idler and recheck them with the sprocket when the frame is installed on the machine.
6. To complete the assembly, the track guiding guards and track roller guards are bolted and welded to the track frame.
7. When all components are installed and aligned, reinstall the track frame on the machine using the same rigging and safety practices described for removal.
8. The track frames must be checked for alignment once installed. Figure 6-149 shows correct alignment of the track frame with the sprocket. Note points 11 and 12 showing the clearances required for proper operation. The sprocket must clear the roller. Also note the diagonal brace clearance, points 14 and 15. To adjust for clearance, the track frame is shimmed in or out.



(6-149)

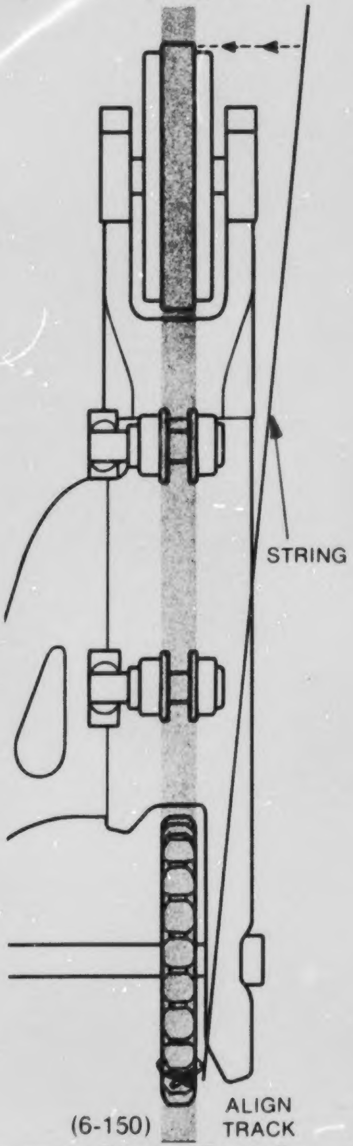
ALIGNING TRACK ROLLER FRAME WITH SPROCKET

1—Cap. 2—Lock. 3—Nut. 4—Retainer. 5—Shims. 6—Holder. 7—Support. 8—Rear track roller. 9—Drive sprocket. 10—Track roller frame. 11—Clearance. 12—Clearance. 13—Diagonal brace. 14—Clearance. 15—Clearance. 16—Steering clutch case.

Courtesy of Caterpillar Tractor Co

ALIGNING THE INDIVIDUAL TRACK SIDES

It is important to recheck the alignment of all the components in respect to the sprocket once the track frame has been installed and the rear roller has been aligned with the sprocket. An easy check is to attach a piece of string to the rear side of the sprocket, as shown in Figure 6-150. Pull the string tight at an angle and move it toward the front idler as indicated by the arrows. When the string is parallel with the side of the sprocket check the relationship of the carrier rollers and front idler and make any necessary adjustments.



(6-150)

Courtesy of Caterpillar Tractor Co

QUESTIONS — UNDERCARRIAGE SERVICE REPAIR

1. List steps required to remove a track.
2. Does it matter which way a track is installed on a crawler dozer?
3. If you are separating the track at the front of the machine, what safety precaution should be taken?
4. Running surfaces on various undercarriage components can be built up with __________. This is done by a ______________.
5. When lifting out a track frame, where should the sling be placed?
6. When removing a press fit sprocket, what precautions must be taken to avoid injuring yourself or damaging the final drive assembly?
7. Can sprocket segments be changed without removing the track? What steps are necessary when installing new segments to ensure that they will stay tight?
8. When a track frame is installed on a machine, what points must be checked for correct clearance? Briefly explain how to correct inadequate clearance.
9. When the track frame, sprocket and idler have been installed, what is a quick method to check their alignment?
10. When a track is installed, the correct ____________ must be put on the track.

ANSWERS — TRACK MACHINE UNDERCARRIAGES

1. — Two track frames
   — The components mounted on the frames
   — The tracks

2. The difference is the way the undercarriages are mounted.

   Dozer track frames can move up and down independently of one another, pivoting from a point near the rear of the tractor. This set up permits maximum track contact with the ground when working in rough terrain.

   Loader track frames, on the other hand, are mounted rigidly, providing a stable working platform.

3. The track frame is a housing to which all the undercarriage components are mounted.

4. — Diagonal brace
   — Guide roller

5. The recoil mechanism is located behind the front idler. Its purpose is to act as a shock absorber and provide some give for the track should something get caught in the tracks.

6. The track adjuster is located in the track frame between the recoil mechanism and the front idler. Three types of track adjusters are:

   — Hydraulic
   — Manual (threaded rod)
   — Combined recoil mechanism and hydraulic track adjuster (gas charged)

7. Use the high position, which puts less strain on the undercarriage when turning, unless the greater stability of the low position is required when the machine is equipped with heavy front-end attachments.

8. A sprocket drives the track. Types of sprockets are:

   — Spoke
   — Disc
   — Ring
   — Segmented

9. Track rollers are bolted to the bottom of the track frame. They support the machine's weight distributing it along the track chain as they run on it.

   The term single and double flange refers to whether the roller has flanges on the outside edges (single) or on both the inside and outside edges (double).

10. Bushings have greater load carrying capacity. Also, they are cheaper and require less space.

11. On the top of the track frame. Their purpose is to support the top of the track as it travels from the sprocket to the front idler.

12. A dozer or loader track consists of two rows of links joined together by pins and bushings with shoes bolted to the links. A shovel track consists of heavy shoes pinned together to form the track. The backs of the shoes are grooved for the rollers to run in, and notched to fit the drive lugs on the tumbler.

13. The distance center to center between two pins.

14. — Master pin
    — Master link

15. A dozer shoe has a raised grouser bar to give the machine traction. A shovel shoe is flat.

16. A double or triple grouser bar shoe.

17. Because the wider the shoe the greater the stress on other undercarriage components.

18. House rollers are placed between the upper and lower works of the shovel or crane and permit the upper works to make a 360° revolution. The rollers travel in a circular path on the lower works. The hook rollers travel in circular grooves under the house roller path and keep the upper works in line.

    Most modern excavators use a large ball bearing circle (an anti-friction bearing) which essentially does the same job as the house and hook rollers.

19. To protect the rollers, pins and bushings from rocks and other debris. Roller guards also help keep the track aligned.

ANSWERS — UNDERCARRIAGE — DAILY, ROUTINE MAINTENANCE

1. Operator's manual for the machine.

2. To spot potential problems and repair them before major damage is done. Check the:

   — tracks

   — track tension

   — sprockets, rollers, carrier rollers, idlers

   — guards and covers

3. Measure the amount of track sag between the idler and the first carrier roller.

4. Tight tracks accelerate wear on undercarriage parts and reduce drawbar horsepower. Loose tracks also accelerate wear on undercarriage parts and increase the chances of a track jumping off.

5. . . . tighten . . . vented. . . . added . . . tighten . . .

6. — Read the venting instructions often located on a decal inside the track adjuster opening, and only turn the vent screw the recommended amount (usually a part of one turn).

   — Keep your face clear of the vent opening.

   — Cover the vent screw with a rag.

   — Place a block in the sprocket and back the machine up to ensure that the pressure is completely relieved.

7. The drive chain. Shims.

ANSWERS — UNDERCARRIAGE SCHEDULED MAINTENANCE

1. — Environment
   — Type of work
   — Speed
   — Operator
2. Internal and external bushing wear and external pin wear. As this wear increases the track stretches. When the track chain stretches the pitch of the chain and the pitch of the sprocket no longer match. The sprocket wears and the tracks loosen, causing accelerated wear to other undercarriage parts.
3. — Pin and bushing wear is almost nonexistant. This greatly reduces wear on the other undercarriage components.
   — Quieter operation.
   — Less friction and thus more available horsepower.
4. The percentage the component is worn before it should be rebuilt.
5. (a) 75 percent
   (b) No. They have gone beyond the rebuild limit and it would not be economical to rebuild them.
6. — Tighten the track. Place a block between the sprocket and track chain and back the machine up.
   — Take a measurement on the top half of track, staying at least two links away from the master pin section.
   — Measure from the front on one pin to the front of the fifth pin away. This measurement will include four links. The total measurement obtained divided by four will give the average worn pitch length. Compare it to the original pitch length and calculate the difference.
7. Turning restores the track pitch.
8. Yes — the sprocket pitch would not match the chain pitch, and therefore accelerated wear would occur to the outside of the bushings.
9. . . . sprocket, rollers, and idler . . . .
10. Uneven wear patterns on undercarriage components under normal working conditions.
11. Wear on wear strips and bearing supports.
12. An idler can be tilted, toed-in or toed-out, or pushed to either side.
13. Measure the distance across the two front roller shafts. Measure the distance across the two rear roller shafts. If the distances are not the same (within a given tolerance), the tracks are not parallel.

ANSWERS — UNDERCARRIAGE SERVICE REPAIR

1. (a) Slacken the track.
   (b) Position the master pin or master link for removal, and separate the track.
   (c) Back the machine off the track onto a plank or raise the machine and pull the track clear of the machine.
2. Yes. The track must be installed so that the grouser bar leads the track towards the front idler.
3. Place a block to support the track when it is released.
4. . . . . weld. . . . welding machine.
5. Around the carrier rollers.
6. — Back off the sprocket retaining nut just enough to allow about 1/4 inch clearance between the sprocket face and the nut; this will prevent the sprocket from flying off when pulled free.
   — Use correct adapters with the puller and pull only against the hub, not against the dead axle.
7. Yes. Clean the bolting surface of drive disc and segments so that they are free of dirt, paint or rust. Torque the bolts evenly and to the recommended pressure.
8. Clearance between:
   (a) The sprocket sides and rear roller flange.
   (b) The diagonal brace and the rear housing on the pivot shaft (if the track frame has a diagonal brace).
   Shim the track frame in or out.
9. Tie a piece of string onto the outside of the sprocket and stretch the string to the front of the idler center flange. Check to see that the sprocket, carrier rollers, and idler center flange all touch the string.
10. . . . . tension . . .

TASKS — TRACK MACHINE UNDERCARRIAGES

Do these tasks on one of the following machines: crawler loader, crawler dozer, excavator, shovel or crane.

DAILY, ROUTINE MAINTENANCE CHECKS

1. Check the undercarriage and its related components for loose bolts, wear, cracks, chips, oil leaks, and any other visible damage. Make any minor repairs; report any major service repair needed.
2. Check the track tension. Adjust it if necessary (refer to adjusting procedures in the track adjuster opening or in the service manual).

SCHEDULED MAINTENANCE

1. Consulting the service manual, do a scheduled lubrication of undercarriage grease fittings.
2. Using a tape measure and following the procedures stated in the service manual, measure the track frame alignment. With wear gauges (if available) or with a measuring tape, measure the wear on the track frame components listed below:

   Front idler
   Idler rollers
   Track rollers
   Pins and bushings

   Record the measurements and look them up on a Percentage Worn Chart. Report parts that have reached or are approaching the rebuild limit. Report any needed repairs or replacements.

SERVICE REPAIR

1. Following procedures outlined in the service manual, slacken the track and position the master link or master pin for convenient removal. Taking safety precautions, remove the master link or pin and with the correct lifting equipment lay the track flat on the ground.
2. Using the correct tools, lifting equipment and procedures outlined in the service manual:
   (a) Jack and securely block the machine at a height at which the track frame can be safely removed.
   (b) Remove the track frame.
   (c) Remove from the track frame the front idler, idler rollers and track rollers. Inspect the components for wear and damage, and repair or replace any that are not serviceable.
   (d) Inspect the track frame for bends, twists, and cracks. Make any minor repairs; report any major service repair needed.
   (e) Repair or replace the track chain assembly.
   (f) Remove and replace the sprocket or sprocket segments.
   (g) Install the track frame components on the track frame and install the frame on the machine. Lower the machine, and install the tracks.
   (h) Following procedures outlined in the service manual, adjust the track tension and lubricate if applicable the front idler, idler rollers, and track rollers.

BLOCK

6

Track Machine Final Drives

PURPOSE OF TRACK FINAL DRIVES

As was seen in Block 5, Power Trains, several assemblies are needed to transmit power from an engine to the tracks. Power from the engine's flywheel is transmitted through a torque converter, transmission, a bevel gear assembly, steering clutch, final drive, and finally to a sprocket which drives the track.

A final drive is basically a reduction gear assembly that converts engine horsepower into powerful torque capable of pulling very heavy loads. The question might be asked, why are final drives necessary? Couldn't a transmission provide this speed reduction and torque increase? The answer is that the transmission would have to be very large to provide the required torque. Also, the tremendous torque or twisting load would have to be carried by all the other power train components from the transmission out. It is much more practical to provide the final reduction at the sprocket where the torque is needed. Final drives have the advantage of giving torque increase while allowing the other power train components to carry lighter loads.

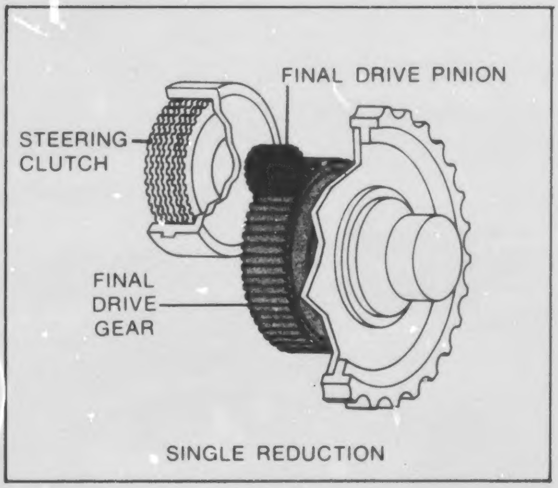
TYPES OF TRACK FINAL DRIVES

There are three types of final drives used on crawler dozers and loaders:

- Single reduction final drives
- Double reduction final drives
- Planetary final drives (outboard and inboard)

Single Reduction Final Drives

Power comes into the final drive through a drive pinion connected to the steering clutch output drum (Figure 6-151). The pinion extends out from the steering clutch housing and is supported by bearings within the housing.

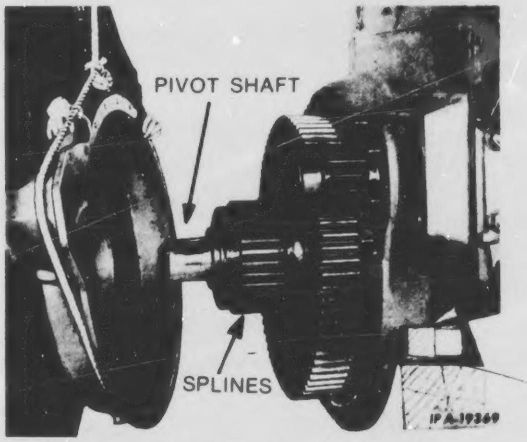


(6-151)

Courtesy of Caterpillar Tractor Co.

The final drive pinion meshes with the large final drive gear. Although it's not clear in Figure 6-151, the sprocket is pressed onto a hub which is either part of the final drive gear or is bolted onto it. Thus, as the final drive gear turns, the sprocket turns.

Some machines have a solid hub, while others have a hollow hub that fits over what is called the sprocket or pivot shaft (Figure 6-152). This shaft is a non-moving "dead" axle pressed into the final drive housing. The final drive gear, hub and sprocket assembly, supported by inner and outer bearings, all turn on the sprocket shaft.



(6-152)

Courtesy of International Harvester

Another function of the sprocket shaft is to support the track frame. This function gives the shaft its other name, pivot shaft. The track frame is attached to the rear of the machine at the sprocket shaft, which acts as a pivot point for the track and track frame to move up or down.

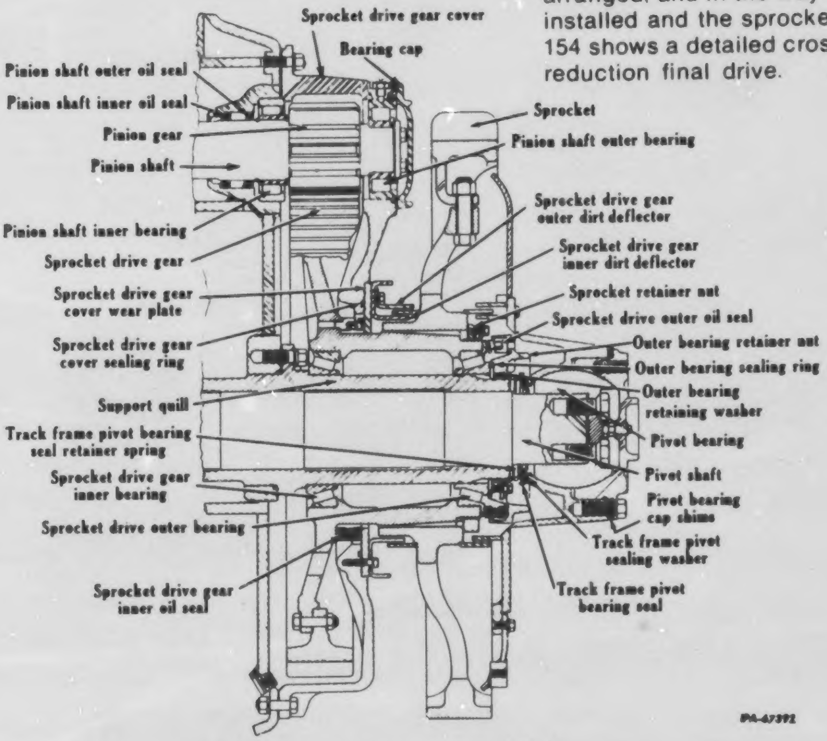
Note that not all machines use this kind of sprocket shaft arrangement. The track frame on these machines are mounted ahead of the final drive housing to a shaft that is attached to the front of the rear main housing. When no sprocket shaft is used, the final drive, gear hub, and sprocket are a live axle and are supported by bearings in the housing and in the case. The final drive case, gears, and shaft can be removed as an assembly (Figure 6-153). Machines that don't have sprocket shafts are generally either smaller tractors such as crawler loaders, or have outboard planetary final drives.

Single reduction final drives use a splash system of lubrication. As the gears move, oil is picked up and splashed throughout the housing.

(6-153)

Courtesy of Massey Ferguson Inc.

The single reduction pinion to final drive gear, either with or without a sprocket shaft, is the most common type of final drive found on middle sized dozers and loaders. There are variations, though, in the way the gears are mounted and the bearings and seals arranged, and in the way the sprocket shaft is installed and the sprocket retained. Figure 6-154 shows a detailed cross-section of a single reduction final drive.

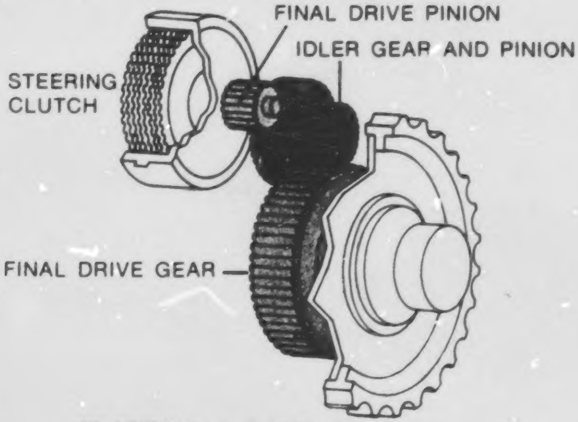

Sprocket drive gear cover
Bearing cap
Pinion shaft outer oil seal
Pinion shaft inner oil seal
Pinion gear
Pinion shaft
Pinion shaft inner bearing
Sprocket drive gear
Sprocket drive gear cover wear plate
Sprocket drive gear cover sealing ring
Support quill
Track frame pivot bearing seal retainer spring
Sprocket drive gear inner bearing
Sprocket drive outer bearing
Sprocket drive gear inner oil seal
Sprocket
Pinion shaft outer bearing
Sprocket drive gear outer dirt deflector
Sprocket drive gear inner dirt deflector
Sprocket retainer nut
Sprocket drive outer oil seal
Outer bearing retainer nut
Outer bearing sealing ring
Outer bearing retaining washer
Pivot bearing
Pivot shaft
Pivot bearing cap shims
Track frame pivot sealing washer
Track frame pivot bearing seal
PA-47392

(6-154) CROSS-SECTION OF SPROCKET DRIVE

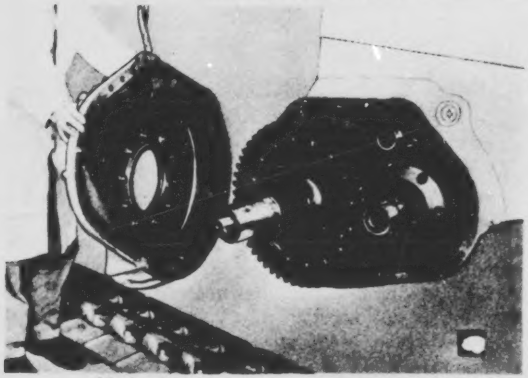
Courtesy of International Harvester

Double Reduction Final Drive

The torque requirements for large tractors with greater horsepower are such that they need a double reduction in the final drive. The double reduction provides a greater torque to the sprocket than a single reduction can give in the same space. Figure 6-155 shows a simplified view and an actual view of a double reduction final drive.



(6-155) DOUBLE REDUCTION
Courtesy of Caterpillar Tractor Co.



(6-155) Courtesy of Caterpillar Tractor Co.

The gear arrangement is essentially the same as in the single reduction except that there is an additional pair of gears, an idler gear and pinion. Sometimes referred to as an intermediate gear and intermediate pinion, these gears are joined together to form a pair or cluster. Power is transmitted from the drive pinion to the idler gear, and then from the idler pinion to the final drive gear, giving two reductions.

A double reduction final drive is assembled similarily to a single reduction except that the double reduction requires extra support for the idler gear and pinion. The bearings have to be adjusted for the final drive gear once the sprocket is installed.

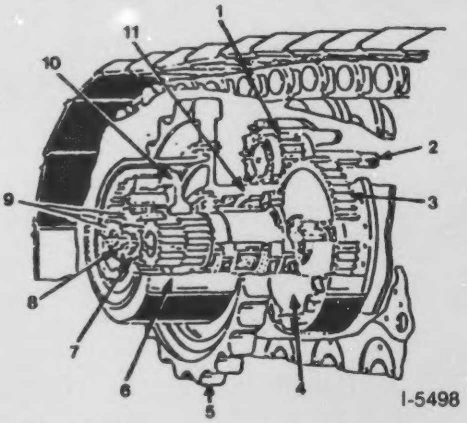
Lubrication for double reduction final drives can be either a splash or a pressure feed system, depending on the size of machine and the manufacturer. In the pressurized system, oil is picked up through a screen at the bottom of the housing by a gear pump driven by a slot at the end of the idler gear. The oil then flows through a full flow filter and is fed to all the vital areas requiring lubrication. Information about the specific flow pattern, pump location, filters and check valves, can be found in the service manual.

Planetary Final Drive

Planetary final drives are found on many tractors, small and large. A planetary gear system has the advantage of:

- — performing a high reduction within a limited space, and
- — allowing the first reduction gears to carry less load and thus to be lighter (reduced gear width).

The planetary final drive is actually a double reduction unit. It uses a pinion-to-bull-gear arrangement for the first reduction and a planetary gear set for the second reduction. The gear combination used to obtain power flow through the planetary final drive is to hold the ring gear, power the sun gear and the carrier is driven at a reduction. Power is supplied to the sprocket from the carrier. Figure 6-156 shows an outboard planetary, outboard meaning located outside the sprocket. There are also inboard planetaries.

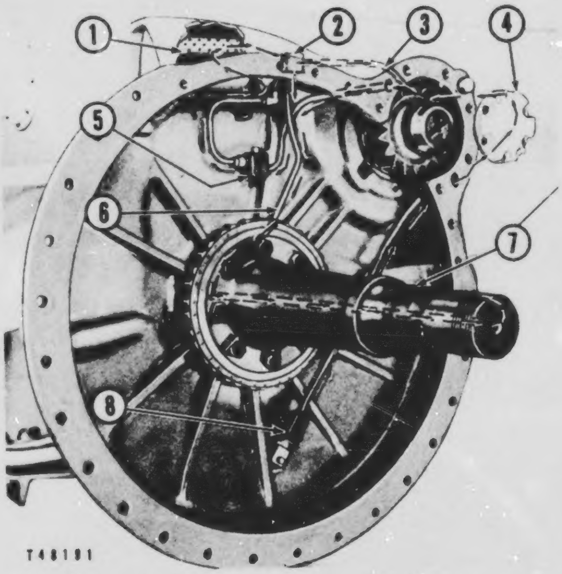


1. Drive Gear
2. Quill Shaft
3. Driven (Bull) Gear
4. Gear Cover
5. Sprocket
6. Planetary Housing
7. Sun Gear
8. Drive Shaft
9. Planetary Pinions
10. Ring Gear
11. Sprocket Hub

(6-156) FINAL DRIVE POWER TRAIN
Courtesy of Terex, General Motors Corporation

To trace the power flow start at the drive pinion (1). Power is transferred to the bull gear (3). Attached to the bull gear by a shaft (8), is the sun gear (7). Therefore, the sun gear is the powered member of the planetary. The ring gear (10) is held stationary (by splines on the housing) and the pinions (9) and their carrier are attached to the sprocket.

Lubrication for the planetary final drives will vary. Outboard planetaries are usually splash fed while inboard planetaries are pressure fed. Figure 6-157 gives a view of a pressure lubrication circuit on an inboard planetary. Note the location of the filter (1), oil pump (4), the check valve (5) that prevents dirt circulating throughout the system when the machine operates in reverse, and the pickup strainer (8). Figure 6-158 gives a detailed cross-section of an outboard planetary.

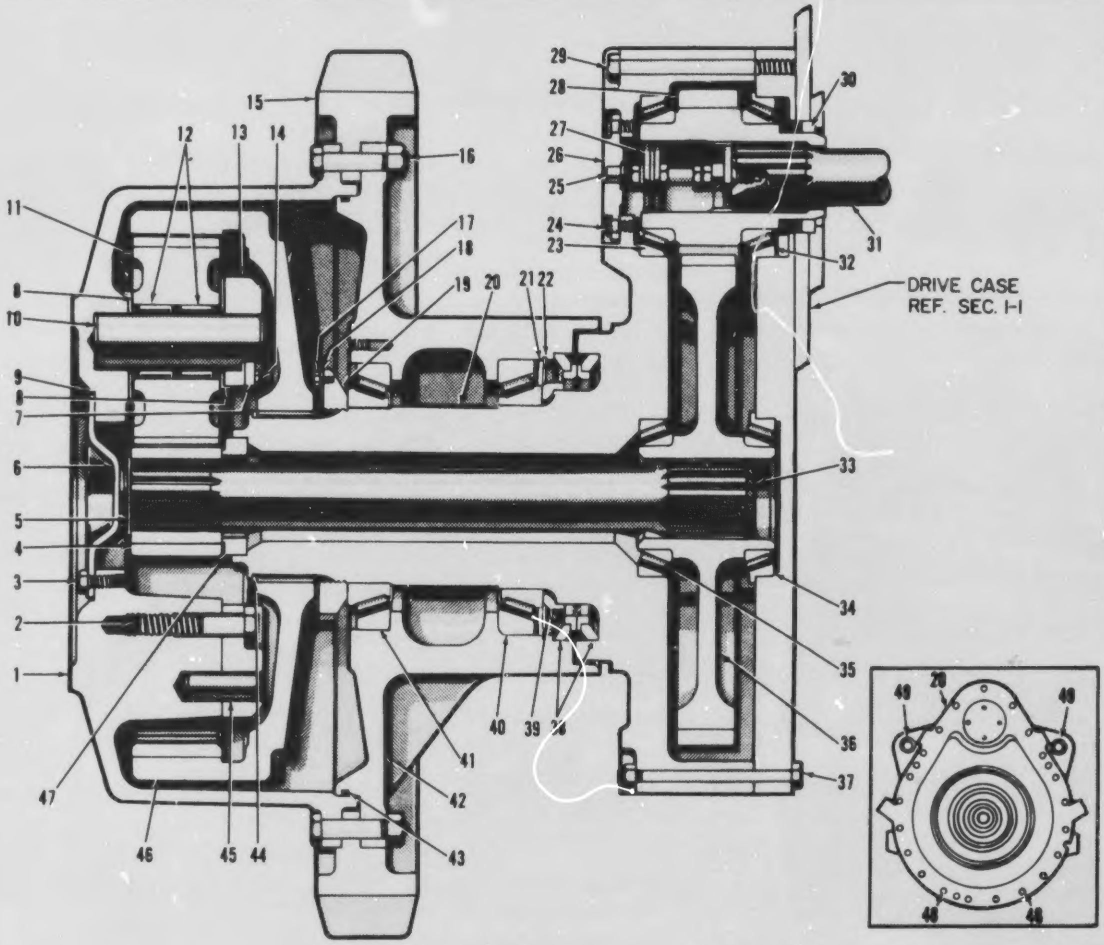


FINAL DRIVE LUBRICATION

1—Oil filter. 2—Junction block. 3—Final drive pinion lubrication line. 4—Oil pump. 5—Ball check valve. 6—Lubrication line. 7—Sprocket shaft. 8—Strainer.

(6-157)

Courtesy of Caterpillar Tractor Co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DRIVE CASE
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1—Planetary Cover
2—Bolts
3—Lock Bolts
4—Sun Gear
5—Snap Ring
6—Thrust Cover
7—Retainers
8—Thrust Washers
9—Gasket
10—Planet Pinion Pins
11—Planet Pinion Gears
12—Bearing Assemblies
13—Ring
14—Bolts
15—Sprocket
16—Bolts & Nuts
17—Bolts & Lockwire
18—Key
19—Lock Nut
20—Gear Cover
21—Puller Disc
22—Snap Ring
23—Bearing Assembly
24—Lock Bolts
25—Thrust Bearing
26—Cover
27—Retainer Assembly
28—Gear
29—Bolts
30—Seal
31—Quill Shaft
32—Bearing Assembly
33—Axle Shaft
34—Bearing Assembly
35—Bearing Assembly
36—Gear
37—Bolts & Nuts
38—Seal Assembly
39—Spacer
40—Bearing Assembly
41—Bearing Assembly
42—Sprocket Hub
43—"O" Ring
44—Snap Ring
45—Dowel
46—Internal Gear
47—Ring
48—Body Fit Bolts & Nuts
49—Threaded Dowel Pins

(6-158) Courtesy of Terex General Motors Corporation

EXCAVATOR, SHOVEL, CRANE FINAL DRIVES

Final drives for excavators, shovels and cranes serve the same purpose as those for dozers and loaders — to reduce the speed and increase the torque to the sprocket or tumblers. These systems generally use one of the following single reduction final drive systems:

- — Chain drive
- — Direct mechanical
- — Hydrostatic — to mechanical gears
- — Hydro-mechanical drive

Chain Drive

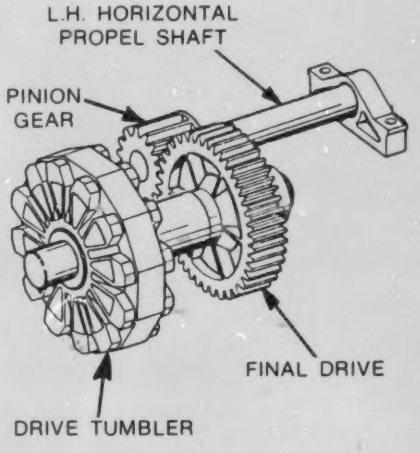
Chain drive is the simplest of the four systems. Power is transmitted from the upper works down to the horizontal propel shaft and out to a small sprocket on either end of the shaft (Figure 6-159). A chain links this small sprocket to a larger sprocket connected to the drive tumbler (see Figure 6-56). The reduction in speed is achieved by a small sprocket driving a large one. Transferring torque by a chain accomplishes the same results as two gears in mesh.

Lubrication on a chain final drive is as follows:

- — the cross shafts are lubricated by grease fittings and
- — the chain and sprockets, since they run in the open, require frequent lubrication which would be done by the service crew or the operator.

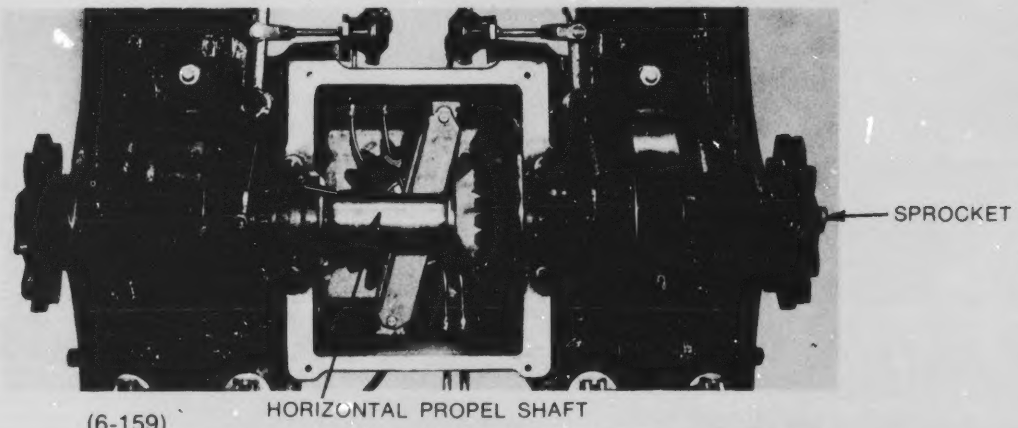
DIRECT GEAR DRIVE

A direct gear drive system is usually found on larger mine shovels. It consists of direct mechanical drive from the upper works through a series of gears to the horizontal propel shaft which in turn supplies power to the pinion gear on the end of the shaft. Power is then transferred to the large final drive gear and out to the drive tumbler (Figure 6-160). The final drive gears are supported by bearings in a housing that is partially filled with oil. Lubrication is by splash.



(6-160)

Courtesy of Harnischfeger Corporation P&H



(6-159)
HORIZONTAL PROPEL SHAFT VIEWED FROM THE BOTTOM OF THE MACHINE LOOKING UP

Courtesy of Bucyrus Erie Co.

HYDROSTATIC FINAL DRIVE

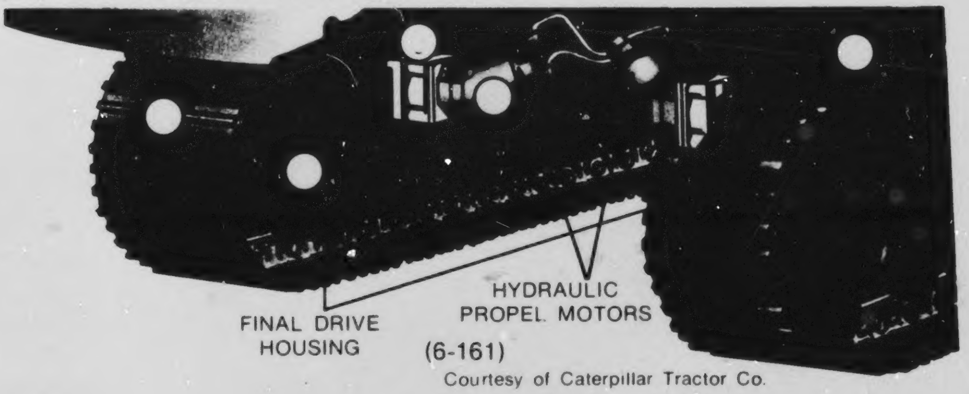
Contrary to its name, the hydrostatic final drive still uses a single reduction gear assembly for the final drive. The hydrostatic refers to the method by which power is supplied to the final drive. A hydraulic motor, not a mechanical gear, drives the pinion of the final drive. No transmission or steering clutches are used. Hydrostatic is a common drive system used on small hydraulic excavators.

Figure 6-161 shows final drive housings located at the rear of the tracks. These housings are partly filled with oil to provide lubrication by splash. Also note the hydraulic propel motors, one for each track.

HYDRO-MECHANICAL DRIVE

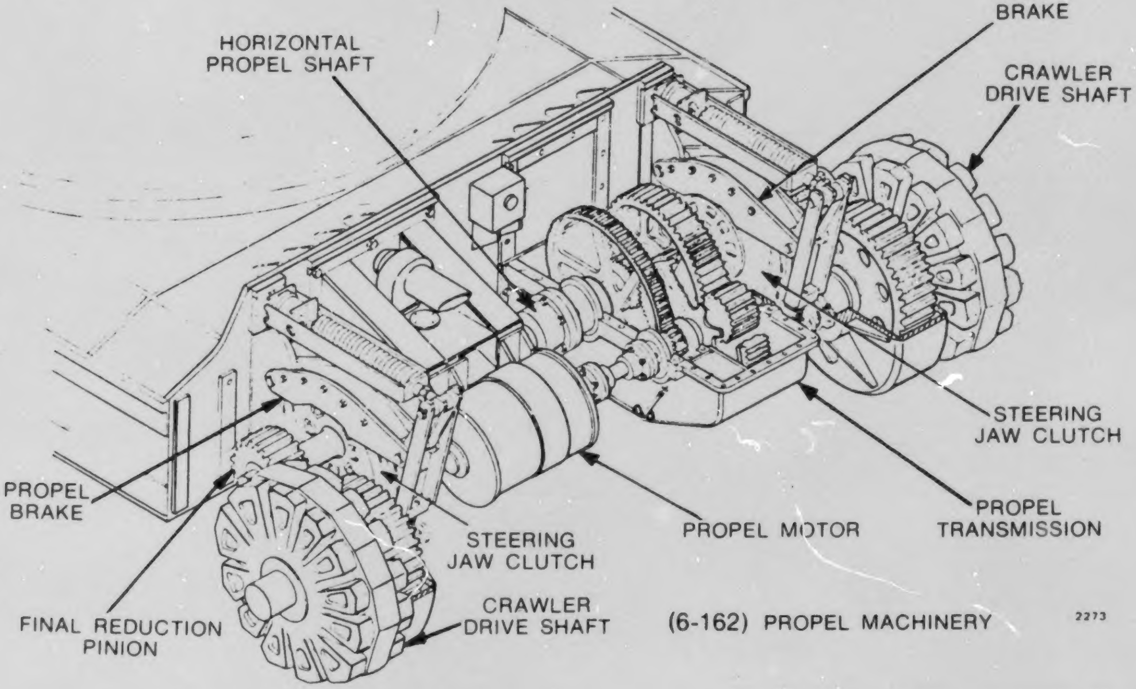
Some of the large mining shovels use a hydraulic motor for propel, but transmit power to the final drive pinions through a transmission and steering clutches. From the pinions out, the same single reduction gear train is enclosed in a housing partially filled with oil and is splash lubricated.

Figure 6-162 shows a complete propel system for a large mining shovel. Note the final drive assemblies for each track and the similarities to the others previously discussed.


HYDRAULIC PROPEL MOTORS
FINAL DRIVE HOUSING

(6-161)

Courtesy of Caterpillar Tractor Co.


PROPEL BRAKE
HORIZONTAL PROPEL SHAFT
CRAWLER DRIVE SHAFT
STEERING JAW CLUTCH
PROPEL BRAKE
PROPEL TRANSMISSION
PROPEL MOTOR
STEERING JAW CLUTCH
FINAL REDUCTION PINION
CRAWLER DRIVE SHAFT
2273

(6-162) PROPEL MACHINERY

Courtesy of Harnischfeger Corporation P&H

QUESTIONS — TRACK MACHINE FINAL DRIVES

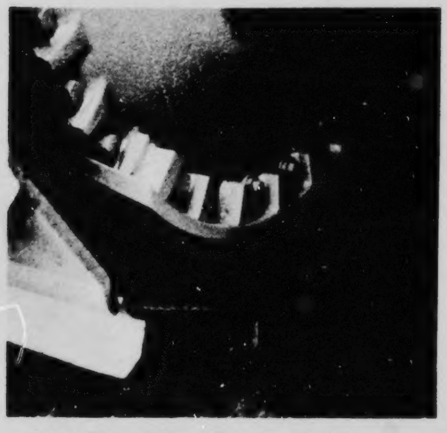
1. What is the purpose of a final drive?
2. What are the three common types of final drives used on crawler machines?
3. A sprocket shaft is a __________ axle press fit into the __________ housing. Supported by inner and outer bearings the __________, __________, and __________ all turn on the sprocket shaft.
4. What is the advantage of a double reduction final drive over a single reduction?
5. Does a planetary final drive give a single or a double reduction?
6. What two methods are used to lubricate final drives? Indicate which method is used for each type of final drive.
7. Briefly explain how a reduction is obtained by a shovel or crane chain drive.
8. True or False? Double reduction final drives are usually found on medium to small size tractors.
9. On a hydrostatic final drive used on many hydraulic excavators, a __________ drives the pinion of the single reduction gear assembly.

FINAL DRIVE MAINTENANCE AND REPAIR

DAILY, ROUTINE MAINTENANCE

Daily, routine maintenance checks for final drives are a relatively simple task that should be included in the Daily Walk Around Inspection. Although most final drives are enclosed in housings and not much can be seen of their gears and bearings, there are some final drive checks that can be made from outside the housing:

1. Check for leaks or signs of leaks at the housing joints and at the sprocket seals.
2. Check for damage under the housing. Housings can be damaged especially if the machine is working in rough terrain. Bolt-on wear plates are available to protect the underside of final drive housings (Figure 6-163)
3. Check the track tension. Tight tracks are hard on final drive bearings and can cause leaks at final drive seals.
4. If the machine is a chain drive (shovel or crane), check the condition of the chain, its lubrication and tension.



Steel Final Drive Guards are bolt-on replaceable plates which protect the exposed portion of the final drive case from ripped rock, large slabs or boulders.

(6-163)

Courtesy of Caterpillar Tractor Co

SCHEDULED MAINTENANCE

Scheduled maintenance on final drives is basically checking and changing the oil and replacing the filter (if there is one) at the time intervals stated in the service manual.

Whenever gears work together minute particles of metal break off the contacting surfaces. Normal gear wear produces small traces of metal filings in the oil. When parts start to fail, however, many more particles chip off and accumulate in the housing, the oil, the filter and also on the magnetic drain plugs found in most gear cases. Thus, by checking for metal particles in the oil, filter and drain plug, you can keep an eye on the condition of the gears.

Many companies use a systematic oil sampling program to keep on top of potential problems. Oil samples are taken regularly from each compartment on the machine and laboratory tested. The results from these tests can indicate minor problems before they become major and also determine the approximate time that major service repair should be done on a component. (See the discussion on Oil Analysis in Block 7, Engines.)

A scheduled maintenance check on a final drive should include:

1. Draining the oil from the final drive housing.
2. Replacing the filter (if equipped).
3. Checking for metal accumulation or better still, having an oil sample analyzed (on a regular basis).
4. Refilling the housing with the correct amount and type of lubricant.
5. Checking to ensure there are no leaks.

SERVICE REPAIR ON FINAL DRIVES

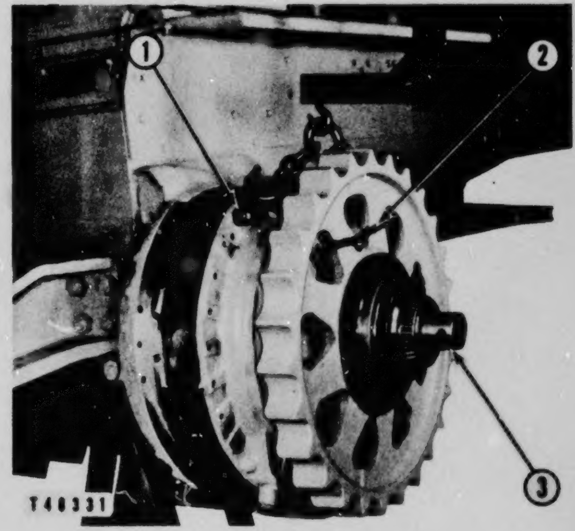
Signs of final drive problems are (1) an accumulation of metal chips in the final drive oil, (2) leaks at the sprocket seal and (3) noisy final drive gears. Not paying attention to these warning signs could lead to a complete break down of the final drive.

Although machines have different sprockets and final drives, the basic steps involved in gaining access to the final drive and in disassembling its gears and bearings are fairly similar. Following is some general information on final drive removal and repair. Detailed service procedures for specific final drives are found in service manuals.

Final Drive Removal

1. Depending on the machine, to get at the final drive:
    - (a) The track has to be disconnected (it's most convenient to break the track at the sprocket end).
    - (b) The track may have to be removed.
    - (c) The track and track frame both may have to be removed.
2. Raise the machine and block it securely with large wood blocks or with the correct size metal stand.
3. A general rule before disassembling any component is to clean the outside of the housing(s) at the gasket joints. It is a poor practice to open up a gear case without first cleaning it (even if the gears inside are damaged) because dirt can get inside the case and once there, is difficult to clean. Note that when reassembling a gear case all dirt must be removed from the housing because the dirt can damage the moving parts.

    A steam cleaner or high pressure washer is ideal for cleaning housing joints. When this equipment is not available (i.e., in the field), use a wire brush to remove the bulk of the dirt, and a bristle brush and solvent to complete the job.
4. After the outside of the housing is cleaned drain the oil.
5. There are various ways of removing and disassembling final drives. Figure 6-164 shows a sprocket and final drive being removed as an assembly. Figure 6-165 shows a single reduction final drive being removed, (the sprocket has already been pulled). Figure 6-166 shows the removal of an inboard planetary final drive.

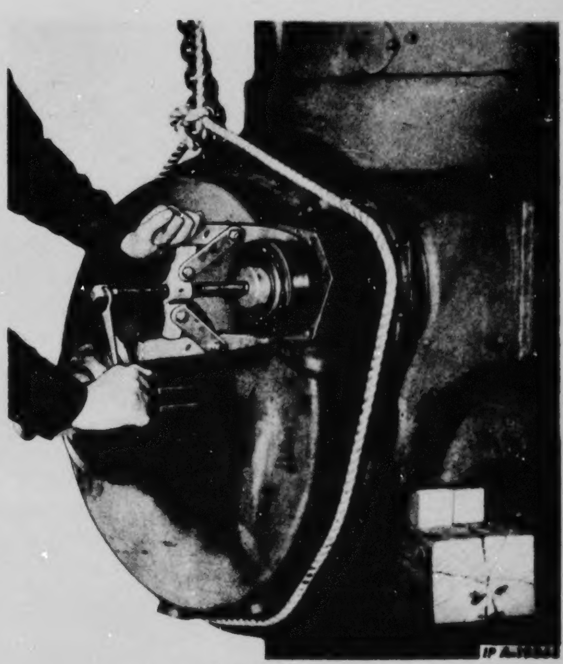


(6-164)

REMOVING FINAL DRIVE ASSEMBLY

1—Rear bracket. 2—Chain. 3—8M4856 Sleeve

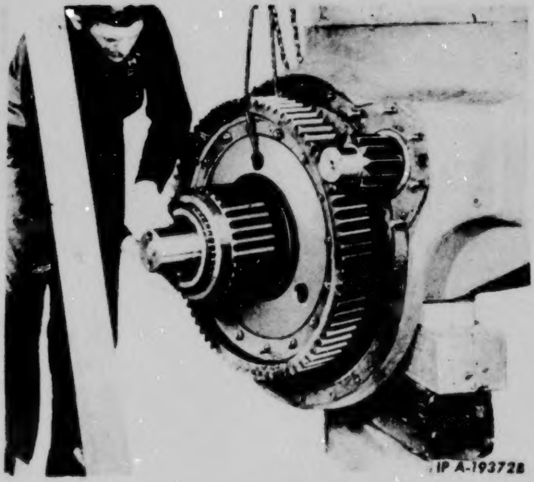
Courtesy of Caterpillar Tractor Co.



(6-165)

REMOVING PINION SHAFT OUTER BEARING

Courtesy of International Harvester



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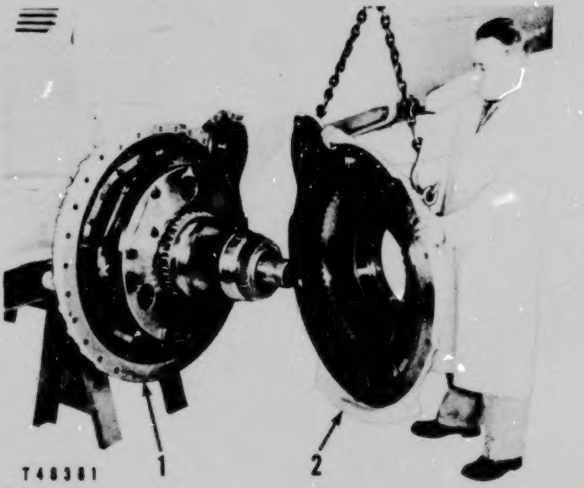
Courtesy of International Harvester

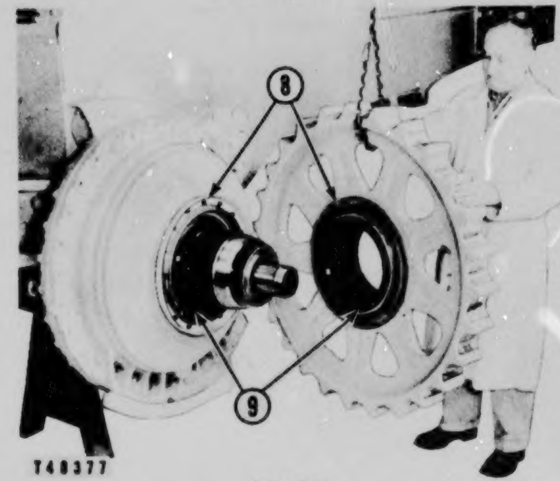


(6-166)

REMOVING FINAL DRIVE CASE

1—Steering clutch case. 2—Final drive case.

Courtesy of Caterpillar Tractor Co

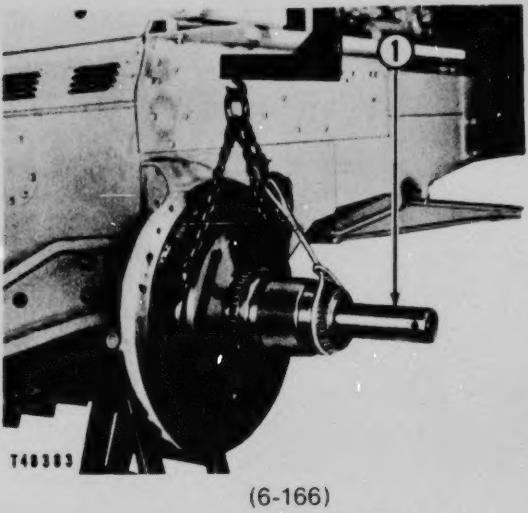


(6-166)

REMOVING SPROCKET

8—Guards. 9—Metal floating ring seals.

Courtesy of Caterpillar Tractor Co



(6-166)

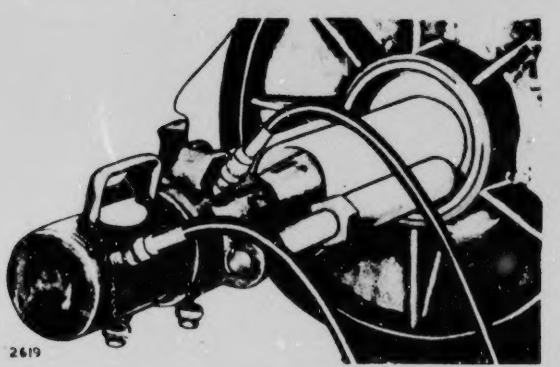
PLANET CARRIER REMOVAL

1—8M4856 Sleeve.

Courtesy of Caterpillar Tractor Co

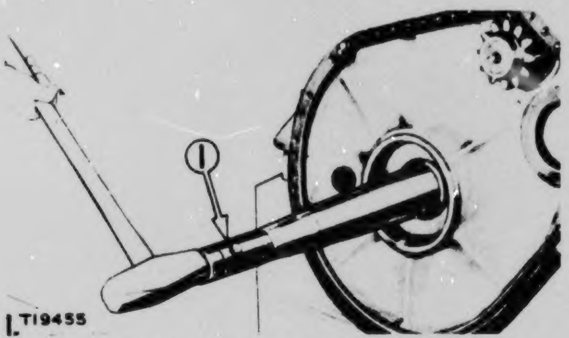
Removing and installing Sprocket Shaft

A hydraulic press is needed to remove a dead axle that is bent beyond allowable tolerances (Figure 167). To install a new shaft, a threaded adapter is screwed onto the shaft, and then the shaft is driven with a sledge hammer tight on its taper in the housing (Figure 168). The shaft is then retained by whatever means the particular manufacturer uses.



(6-167) PULLING SPROCKET SHAFT

Courtesy of Caterpillar Tractor Co.



(6-168) INSTALLING SPROCKET SHAFT

1—5F9879 Adapter.

Courtesy of Caterpillar Tractor Co.

When the shaft is driven fully in, measure the distance from the end of the shaft to the housing and check the figure against the specifications in the manual. Should this measurement be less than the required amount (i.e., the shaft is too far in), a worn taper is indicated. The housing will have to be bored and a sleeve installed, a job that would be done by a machine shop.

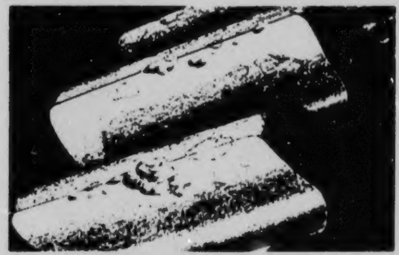
EXAMINING FINAL DRIVE GEARS

If gear teeth are broken the gear is automatically replaced; if the teeth are not broken a thorough inspection for potential failure spots should be made. A magnaflux machine or similar crack testing equipment is the most reliable way of checking gears. If such testing equipment is not available, a visual inspection may be sufficient. By accumulating knowledge and experience of gear wear, it's possible to tell by sight when a gear is worn to the point that it has to be replaced. The apprentice should seek the help of a journeyperson in judging whether a gear can be reused.

Two factors should be kept in mind when deciding whether to reuse or to replace gears:

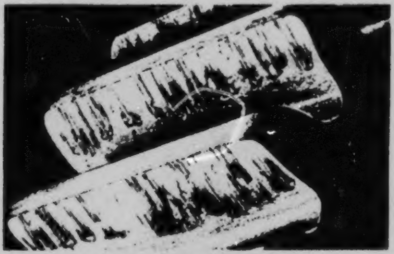
1. Final drive gears have to carry extremely heavy loads.
2. It is very expensive to have to repair a final drive that breaks not long after it goes back into service.

Types of Gear Wear



(6-169) SPALLING

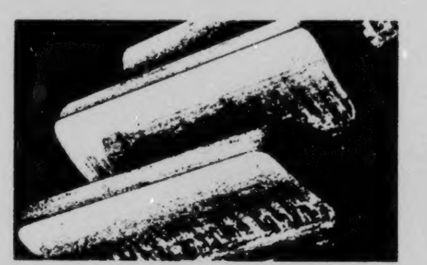
Spalling — Spalling is a common wear condition which starts with fine surface cracks and eventually results in large flakes or chips leaving the tooth face. Case-hardened teeth are most often subject to this kind of damage due to the brittle nature of the metal. Spalling may occur on one or two teeth but the chips may cause other damage to the remaining teeth.



(6-169) ABRASIVE WEAR

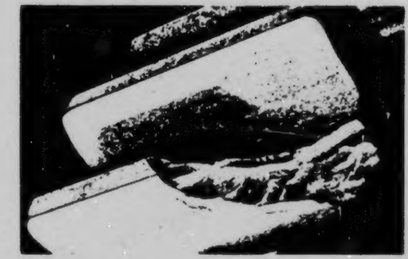
Abrasive Wear — Surface injury caused by fine particles carried in the lubricant or embedded in the tooth surfaces. The causes are metal particles from gear teeth, abrasives left in the gear case, or sand and scale from castings.

Interference Wear — This type of wear can be caused by misalignment of gears which places heavy stress on small areas. Also, mating of two gears with teeth not designed to work together will cause interference wear. More than one wear pattern may show up, as at teeth tips and roots. Possible causes of interference wear on final drive gears could be loose final drive bearings or a bent dead axle. If the machine is run very long with these problems, the interference wear would lead to gear failure.



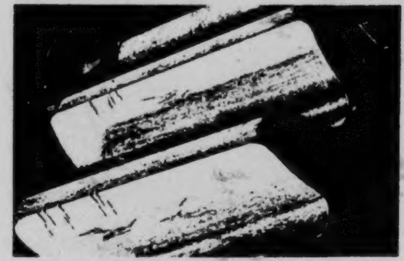
(6-169) INTERFERENCE WEAR

Breakage — Broken teeth may be the result of many defects. Make a close study of the other teeth before judging the cause. Breakage can be caused by high impact forces or defective manufacture. To determine if breakage is due to overload or fatigue, examine the broken area closely. If the break shows fresh metal all over the break, an impact overload was the cause. If the break shows an area in the center of fresh metal with the edges dark and old-looking, the breakage was due to fatigue which started with a fine surface crack. Final drive gears take great stress and often get broken.



(6-169) BREAKAGE

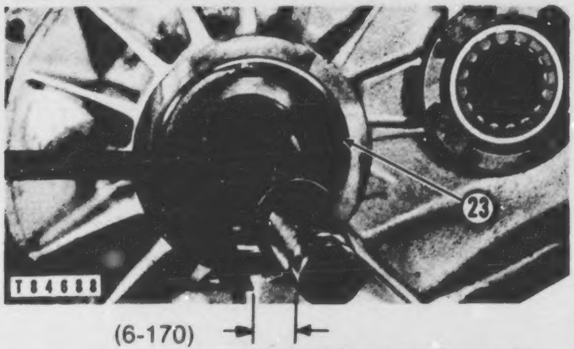
Cracking — These failures tend to be caused by improper heat treating during manufacture. Improperly machined tooth root dimensions can also result in cracking. Most cracks caused by heat treatment are extremely fine and do not show up until a gear has been used for some time.



(6-169) CRACKING

FINAL DRIVE REPAIR

1. Generally speaking, when a final drive is repaired, its bearings and seals are replaced. Always keep the old bearings and seals and compare them with the new to ensure that the right ones are put back into the machine. The exception to the rule that final drive seals are replaced is metal face seals (however, their tension rings are always replaced). Examine the face seals to see if they can be reused, and if so, clean them, tie them together as a pair and store them in a dry place.
2. Pressurized oil systems on final drives have to be completely disassembled and cleaned. Also, the filter and any worn or damaged parts should be replaced.
3. Whenever a major final drive gear failure occurs (and in general any gear failure), metal chips and filings will gather in every possible corner. Be absolutely certain that the lubrication system and the housing are free of these chips and filings or the rebuilt final drive will be prematurely damaged and fail.
4. Check that the dead axle is straight. Bending of the axle usually occurs front to back because of the loads imposed on the track frame from the front. A misaligned dead axle can cause premature failure to a rebuilt final drive. To check the dead axle, place a carpenter's square horizontally on the machined faces of the housing to the rear side of the dead axle (Figure 6-170). Keep the other leg of the square parallel to the shaft and measure the distance between the end of the shaft and the square. Take a similar measurement at the front side of the axle. The two measurements should be the same. If they are not, check the service manual for the maximum bend allowable. As an example, a caterpillar D6 tractor allows .125" (3.2 mm) maximum bend.



(6-170)

Courtesy of Caterpillar Tractor Co.

5. Thoroughly check the final drive housing for cracks, and especially check the side for thin spots. This area of the housing receives a lot of abrasive wear. As was mentioned earlier wear strips can be welded to the housing underside, but if the housing is too damaged it may have to be replaced. Clean the bolting face of the housings with a file to remove burrs and high spots.
6. Before ordering parts, check all tapers and splines because wear at those points will allow press fit parts such as sprockets to work loose in a short time.
7. Some installation points:
   - — pre-lube all final drive bearings and gears before installing.
   - — use care not to damage seals when installing them.
   - — when a sprocket is press fit be sure it is pressed with the correct tonnage.
   - — when the track frame is removed to work on a final drive be sure on reassembly that the sprocket and rear track roller have sufficient clearance, and as well, that both sides of the diagonal brace have proper clearance (see track frame service repair).
   - — after filling the housing with the correct type and amount of oil, check that the drain plug is tight and that there are no leaks at the joints.
   - — refer to service manual specifications for all adjustments.

QUESTIONS — TRACK MACHINE FINAL DRIVE MAINTENANCE AND REPAIR

1. How do tight tracks affect final drives and what would be a sign of such an effect?
2. If a large accumulation of metal chips are found in the oil drained from a final drive, what would be the correct action to take?
   - (a) Reinstall the drain plug and put in heavier oil.
   - (b) Flush out the housing, install a new filter and oil.
   - (c) Report to your supervisor the problem and schedule the machine for repair.
   - (d) Start disassembling it right away.
3. List two obvious signs of a final drive problem.
4. Briefly list the steps involved in removing a final drive.
5. When removing a final drive, what should be done with the metal face seals?
6. What is the most reliable way of checking the serviceability of final drive gears?
7. What is the accepted practice regarding bearings and seals when overhauling a final drive?
8. How would a bent dead axle, if not detected during overhaul, affect a rebuilt final drive?

ANSWERS — TRACK MACHINE FINAL DRIVES

1. It provides a torque increase at the sprocket allowing the other power train components to carry lighter loads.

2. Single reduction

   Double reduction

   Planetary (outboard and inboard)

3. . . . dead . . . final drive . . . final drive gear, hub, and sprocket . . . .

4. Within approximately the same space, a double reduction final drive provides a greater torque increase than a single reduction.

5. Considering the whole assembly, it gives a double reduction. The first reduction occurs at spur gears, (pinion to bull or final drive gear), and the second reduction at the planetary.

6. Splash feed — single reduction and outboard planetary

   Pressure feed — double reduction and inboard planetary

7. A small sprocket drives, by way of the chain, a large sprocket creating a reduction; just as a small gear driving a large gear creates a reduction.

8. False. They are found on large tractors.

9. . . . hydraulic motor . . . .

ANSWERS — TRACK MACHINE FINAL DRIVE MAINTENANCE AND REPAIR

1. Tight tracks are hard on final drive bearings and can cause final drive seals to leak.
2. (c) Report to your supervisor the problem and schedule the machine for repair.
3. — An accumulation of metal chips in the final drive oil.
   — Leak at the sprocket seal.
   — Noise from the final drive gears.
4. — Disconnect the track and lay it out of the way.
   — The track frame may have to be removed.
   — Clean the housing around the parting faces.
   — Drain the oil.
   — Remove the sprocket.
   — Remove the cover and gears.
5. Examine them for possible reuse. If they can be reused, clean them, tie them together, and store them in a dry place.
6. By magnaflux or similar crack detecting equipment.
7. Replace them with new ones.
8. A bent dead axle would cause premature failure of the gears or bearings.

TASKS — TRACK MACHINE FINAL DRIVE

ROUTINE MAINTENANCE CHECKS

Check the final drive for leaks at seals and gasket joints and for any other visible damage. Report any major service repair needed.

SCHEDULED MAINTENANCE

Scheduled maintenance procedures from the service manual for final drives include the following:

1. Drain the final drive housing, inspect the oil for metal chips and signs of moisture. Report any chips or moisture detected, making recommendations for needed repairs.
2. Replace the drain plug and refill the housing with the correct type and amount of lubricant.

SERVICE REPAIR

This task must be done when the track machine is raised and has the track, track frame and sprocket removed.

Using the correct tools, equipment and procedures outlined in the service manual:

1. Take a suitable size container and drain the oil from the final drive housing.
2. Clean the housing and remove the final drive housing and gears.
3. Disassemble, clean, inspect the gears, bearings and seals for wear and damage. Write a service report or parts list and repair or replace any parts that are not serviceable.
4. Disassemble, clean, inspect and replace non-serviceable parts in the final drive lubrication system.
5. Practising cleanliness, prelubricate and install the final drive gears and housing.
6. Install the sprocket, and adjust the bearings.
7. Fill the final drive unit with the correct type and amount of oil and ensure there are no leaks.

BLOCK

6

Track Machine Steering

HOW TRACKS ARE TURNED

To turn a crawler, machine power has to be cut to one track and then the driven track will turn the machine in the direction of the track that has lost power. Most crawlers interrupt the flow of power to a track by means of steering clutches. There are three basic types of steering systems: multi-disc clutch, planetary gear, and jaw clutch.

Another method of interrupting power flow to a track is by the use of hydrostatic steering. Hydraulically propelled machines, such as hydraulic excavators, have a hydraulic drive train component that controls power to the tracks. As well as transmitting power for straight ahead travel, this component can cut power to either track and thus provides a means of steering the machine. Hydrostatic steering is a trend in modern crawlers; for example, John Deere is now using it on one of its crawler dozers.

Crawler steering is related to the type of crawler and in some cases to the manufacturer. For example, International Harvester is the main user of planetary clutches. Crawler dozers or loaders use multi-disc or planetary steering clutches; shovels and cranes use jaw clutches; hydraulic excavators use hydrostatic steering.

STEERING CLUTCHES AND BRAKES

Steering clutches are usually located in compartments at the rear of the machine, between the bevel gears and the final drive assemblies. There is one steering clutch for each track. Incorporated with each steering clutch is a brake. Besides providing braking for a machine, this brake is also used as an aid in making a turn. Cutting the power to one track leaves one track driving and the other in neutral (i.e., free to move with the momentum of the other track). The result is that the machine makes a slow turn towards the track in neutral. On the other hand, when a combination clutch-brake turn is made (clutch disengaged, brake applied same side), the track without power will not be able to roll freely but instead will slow down or completely stop depending on how much brake is applied. Braking the track causes the machine to make anything from a gradual turn to an abrupt sharp turn. This combination clutch-brake turn is called a pivot turn.

Operating controls (pedals or hand levers) for steering clutches and brakes vary with the machine. Some machines use separate clutch and brake controls, whereas others combine them. Steering and braking controls are discussed in greater detail later in this section.

MULTIPLE DISC STEERING CLUTCHES

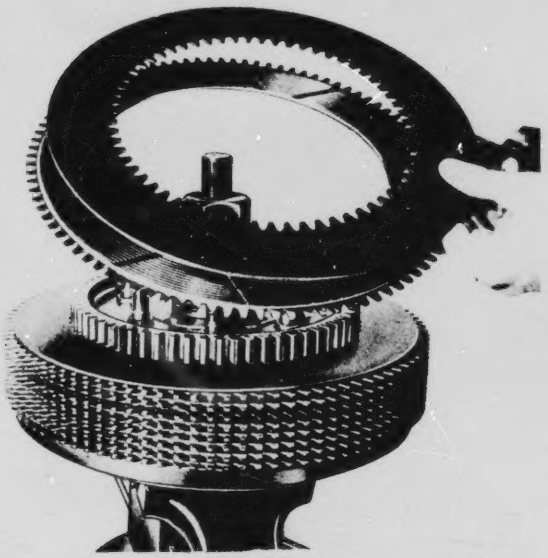
Before looking at multiple disc steering, the most common track steering system, it will be helpful to give a brief review of the material on clutches covered in Block 5, Power Trains.

Clutches transmit power by friction. Engine clutches have three basic parts: a drive member, a driven member and a release mechanism. Power is transmitted only when the driven member is held firmly against the drive member. Clutch holding power or capacity can be increased by adding more driving and driven plates. The capacity of an engine clutch is increased for heavy duty service by adding both an intermediate pressure plate, driven by lugs in the flywheel, and a friction disc splined onto the transmission shaft. For powershift transmissions still more plates are added to form what is called a clutch pack.

A multiple disc steering clutch is a clutch pack. In consists of a:

1. Splined inner drum (the drive member) attached to a bevel gear shaft.
2. Splined outer drum (the driven member) connected to the final drive pinion shaft.

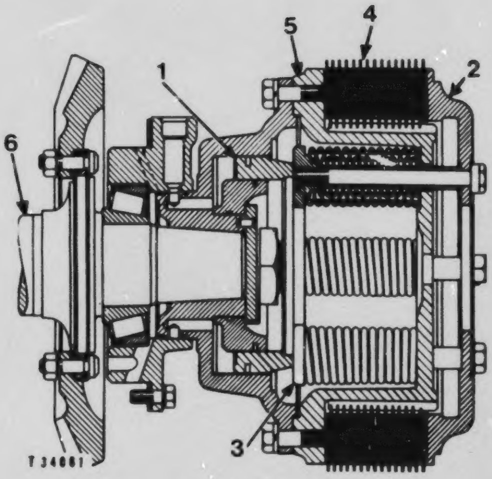
3. Set of internally splined discs alternating with a set of externally splined discs (Figure 6-171). The internally splined discs fit onto splines on the inner drum, the drive member. The externally splined discs fit into splines inside the outer drum, the driven member. The discs are held in contact by springs and pressure plates. Note that the internally splined discs are usually smooth steel, while the externally splined discs are faced with an asbestos material in dry clutches or a sintered bronze material in wet clutches.



(6-171)
Courtesy of Massey Ferguson Inc.

Figure 6-172 shows a typical multi-disc clutch. The output drum, which also acts as the clutch brake drum, has been removed to show the internal parts. This assembly is spring-applied and hydraulically released. Note the number of coil springs in the center and the hydraulic piston for release.

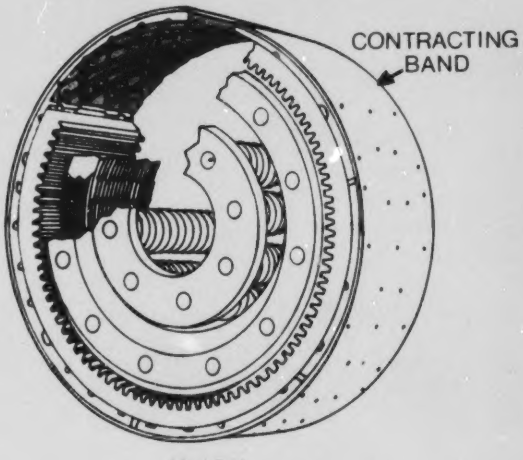
The same basic design of multiple disc clutches has been used since the earliest crawlers were made. There have been improvements in the design, though, such as the addition of a hydraulic release and the change to wet operation. Having the clutches run wet in oil helps them to engage and disengage more smoothly, run cooler and wear longer. Wet clutches can withstand considerable abuse and last much longer than dry clutches.



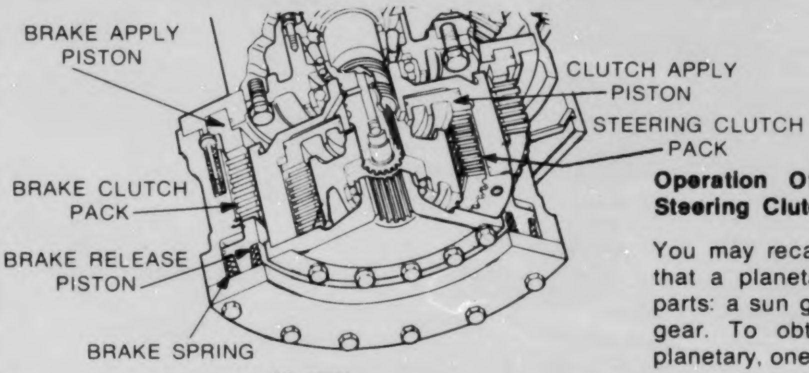
STEERING CLUTCH OPERATION
1—Piston. 2—Pressure plate. 3—Retainer. 4—Discs. 5—Steering clutch driving drum. 6—Bevel gear shaft.

(6-172)
Courtesy of Caterpillar Tractor Co.

Working in conjunction with multi-disc steering clutches is a band-type brake wrapped around the outside of the output drum (Figure 6-173). There is one brake for each track. The two brakes can be applied separately along with a clutch release to give a sharp turn, or applied together to slow or stop the machine on a steep grade. A variation of the band brake is a multi-disc brake, used by Terex; this disc brake is mounted on the outer perimeter of each steering clutch as seen in Figure 6-174.



(6-173)
Courtesy of Caterpillar Tractor Co.



(6-174)

Courtesy of Terex. General Motors Corporation

Other differences in the Terex machine steering clutch and brake are:

1. During normal operation with both tracks driving, the Terex clutch packs are hydraulically applied (not spring-applied) and hydraulically released.
2. When the machine is not running, the Terex multi-disc brake is spring-applied. Once the machine is started, hydraulic pressure (approximately 110 p.s.i.) causes the spring to release the brakes. During normal operation the multi-disc brake is hydraulically applied. Hence, the difference with a band brake is that it releases when the machine is not running unless it is manually applied.

For more specific details of multiple disc steering clutches refer to service manuals.

PLANETARY STEERING CLUTCH

International Harvester has planetary steering systems on their mid and large size dozers and loaders. Single or two speed planetaries are used depending on the size of the machine. A multiple disc brake is employed in conjunction with single speed units whereas a single disc brake is used on the two speed. (The exception is the TD20E which has a drive clutch pack and a brake clutch pack.

The steering planetary unit functions as an intermediate drive; it's located crossways in the tractor between the transmission and the final drive. The planetary provides a gear reduction and permits a power disconnection on each side for turning the tractor. Power to the tracks is transmitted from the bevel gear carrier to the planetary gear carrier and then on through the planetary to the sprocket drive pinion shafts.

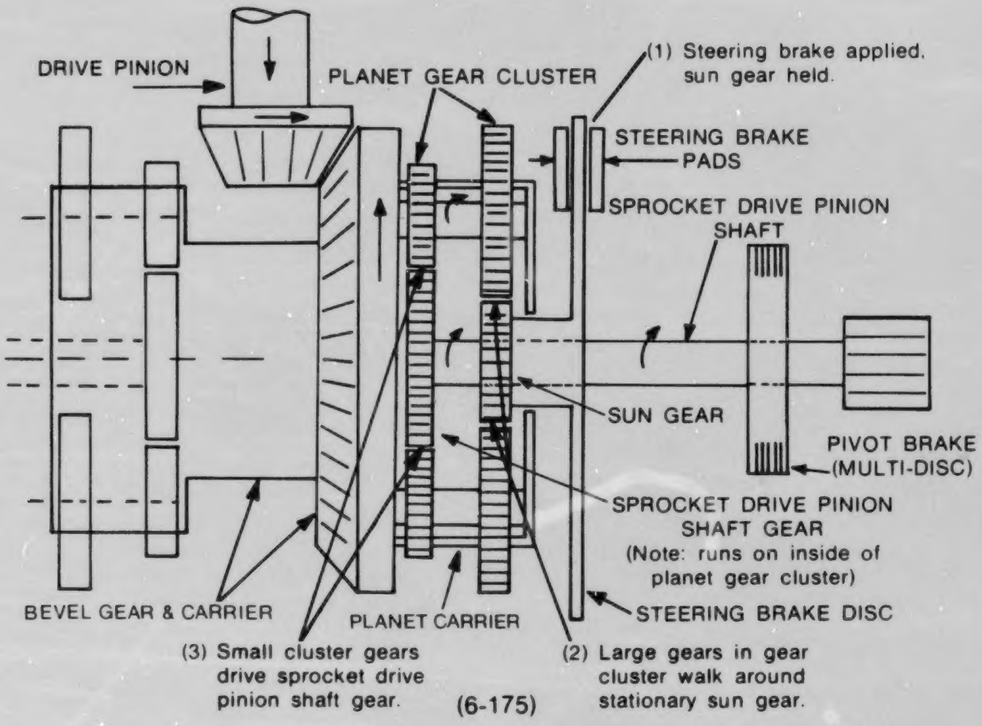
Operation Of A Single Speed Planetary Steering Clutch

You may recall from Block 5, Power Trains, that a planetary gear set consists of three parts: a sun gear, a planet carrier and a ring gear. To obtain a power flow through a planetary, one gear must be held, one must be powered, and the third will be driven.

In a planetary steering system engine power is transmitted to the bevel gear via the transmission and pinion. The bevel gear carrier drives the planetary carrier and its gear clusters. The planet carrier (gear clusters), therefore, is the powered gear. The steering brake disc is attached to the sun gear hub; thus the sun gear is the held gear of the planetary. In the normal planetary gear set, that would leave the ring gear as the driven gear. However, the steering clutch planetary is different in that there is no ring gear as such; the sprocket drive pinion shaft gear replaces the ring gear, and instead of running on the outside of the planet gears, the pinion shaft gear runs on the inside of them. The action of these three gears is very difficult to describe in words, but see if you can follow the gear sequence described in the simplified planetary diagram below (Figure 6-175).

The following sequence occurs when a planetary steering clutch is disengaged:

1. When the steering brake is applied the sun gear is held.
2. The bevel gear powers the planetary carrier and as it rotates causes the large gears in its gear cluster to walk around the stationary sun gear.
3. At the same time that the large cluster gears walk around the sun, the small cluster gears, being mounted on the same shaft, walk around and drive the sprocket drive pinion shaft gear causing it to rotate.
4. The sprocket drive pinion shaft gear drives the sprocket drive pinion shaft which, in turn, drives the final drive pinion and so on. Power is transmitted through the planetary to the final drive and finally to the sprocket, which propels the machine.


DRIVE PINION
PLANET GEAR CLUSTER
(1) Steering brake applied, sun gear held.
STEERING BRAKE PADS
SPROCKET DRIVE PINION SHAFT
SUN GEAR
PIVOT BRAKE (MULTI-DISC)
SPROCKET DRIVE PINION SHAFT GEAR (Note: runs on inside of planet gear cluster)
STEERING BRAKE DISC
BEVEL GEAR & CARRIER
PLANET CARRIER
(3) Small cluster gears drive sprocket drive pinion shaft gear.
(2) Large gears in gear cluster walk around stationary sun gear.

(6-175)

In normal operation, when the machine is moving straight ahead, both steering brake discs are applied so that both sun gears (one on each side) are held and power is transmitted with a slight reduction through the planetaries to drive the machine. If the right steering brake (note that steering brakes are sometimes referred to as clutches or clutch controls) is released, the right side will idle and, the machine will make a slow turn to the right because the left track continues to drive. Similarily, if the left steering brake is released the machine will turn slowly to the left.

On a slow turn the track without power still turns with the momentum of the machine just as the wheels on a moving car will continue to turn when the transmission is shifted to neutral. When the operator requires a sharper turn, he applies the multi-disc pivot brake which will slow or stop the sprocket drive pinion shaft (and thus slow or stop the track), allowing for a much sharper turn. The descriptions below tells what happens in the planetary (1) when its idling and (2) when the multi-disc brake is applied.

Planetary Operation

Planetary In Idling Motion (Refer To Figure 6-175)

1. The sun gear is released and free to move.
2. The carrier (always moving) will drive the sun gear. Since the sun gear is not connected to any shaft (the sun gear is hollow, the sprocket drive shaft goes through it), it rotates freely.
3. The sprocket drive pinion shaft gear is driven by the momentum of the track and sprocket. The small cluster gears meshed with the pinion shaft gear turn with it.

Planetary With The Multi-Disc Pivot Brake Applied (Refer To Figure 6-175)

1. The pivot brake slows or stops the sprocket drive pinion shaft gear.
2. The small cluster gears of the constantly moving carrier walk around the pinion gear.
3. The large cluster gears drive the freely spinning sun gear.

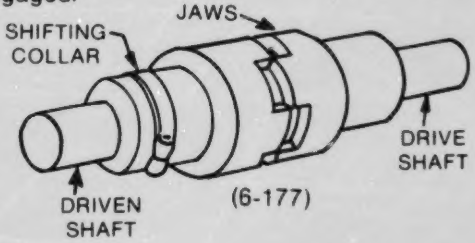
Two Speed Planetary Steering Clutch

The planetary steering clutch described above is a single speed model. On their larger dozers International Harvester uses two speed planetaries (Figure 6-176) which have the advantage that during a gradual turn, power is transmitted to both tracks. The two speed is essentially the same as the single speed except that it has an extra brake giving it a high and a low range steering brake. The additional steering brake has its own sun gear, and the planet carrier has three (opposed to two) cluster gears to accommodate the extra sun gear. On most two speed planetaries both the low and high range brakes are single discs while the recent TD20E two speed has a multi-disc steering brake. Note that only one of the range discs on each side can be held at any one time.

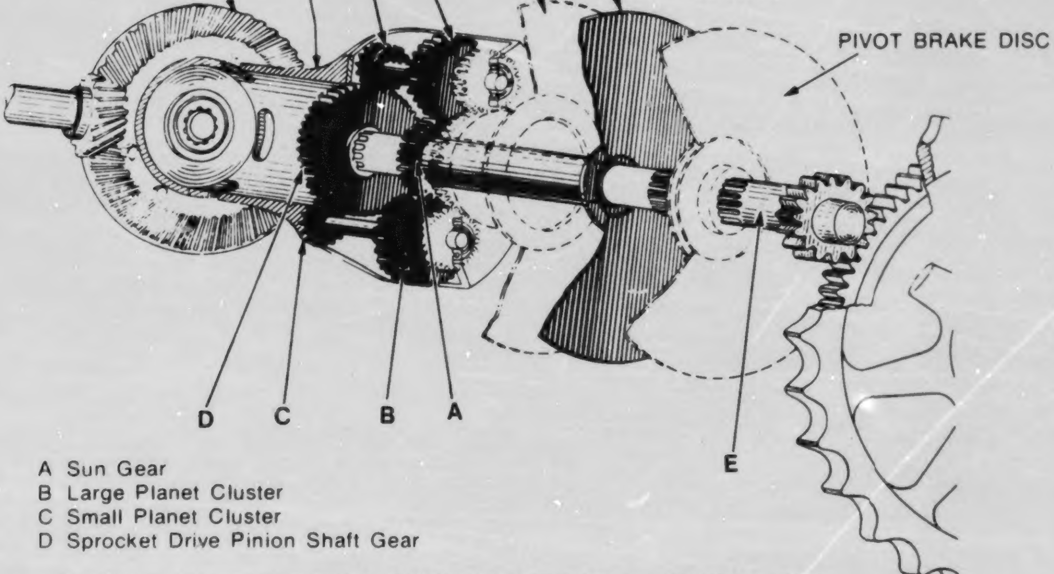
SHOVEL AND CRANE STEERING

Shovels and cranes, like dozers and loaders, require the interruption of power flow to the tracks in order to turn. However, the turning method in shovels and cranes is different than that of dozers and loaders because their work requires a unique type of turn. Normally, a shovel or crane operates in one spot for a period of time then travels only a short distance before it stops and begins work again. Since the movement is slow and the turns are few, a much simpler clutch than a dozer's can be used. Therefore, shovels and cranes employ jaw clutches for steering.

Jaw clutches, as discussed in Block 5 Power Trains, are the simplest of all clutches consisting of two toothed jaws facing one another, one mounted on a drive shaft the other on a driven shaft (Figure 6-177). One jaw is fixed while the other moves on splines, forward to engage the two jaws, backward to disengage them. Jaw clutches can be engaged or disengaged only when the machine is stopped and the propel clutch is disengaged.



(6-177)



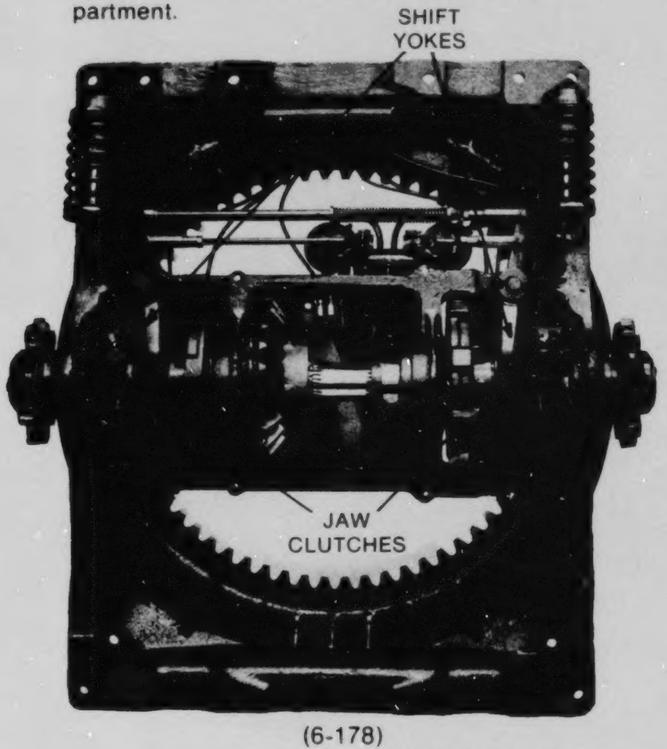
A Sun Gear
B Large Planet Cluster
C Small Planet Cluster
D Sprocket Drive Pinion Shaft Gear

(6-176) PLANETARY SYSTEM, SHOWING THE LINE OF POWER IN THE HIGH RANGE POSITION

Courtesy of International Harvester

As shown in Figure 6-178, shovels use two jaw clutches, one on either side of the bevel gear on the horizontal propel shaft.

The shift yokes operate the movable jaws. On this model shifting is accomplished by air cylinders connected to the linkages. The air cylinder controls are in the operator's compartment.



(6-178)
Courtesy of Bucyrus Erie Co.

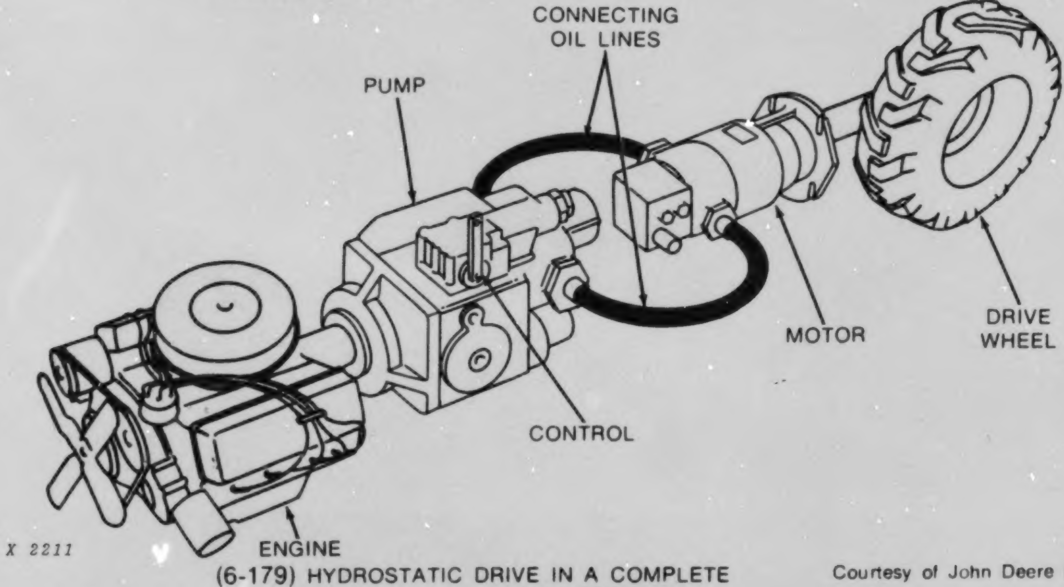
The brakes used with jaw clutches are external contracting bands located toward the outside of the clutches. When applied, the bands grip a drum attached to the propel shaft. These brakes shown here are spring-applied and air-released. Jaw clutch and brake controls will be discussed in detail later in this block.

HYDROSTATIC STEERING

The basic principles of hydrostatic steering are dealt with here; it is covered in more detail in later training.

Hydrostatic drive is an automatic fluid drive using fluid under pressure to transmit engine power to the drive wheels or tracks. In this sytem mechanical power from the engine is converted to hydraulic power by a pump and a motor. The hydraulic power is then converted back to mechanical power to drive the machine (Figure 6-179).

The hydrostatic drive can function as both a clutch and transmission. The final gear train can then be simplified because the hydrostatic unit will provide infinite speed and torque ranges as well as reverse speeds.

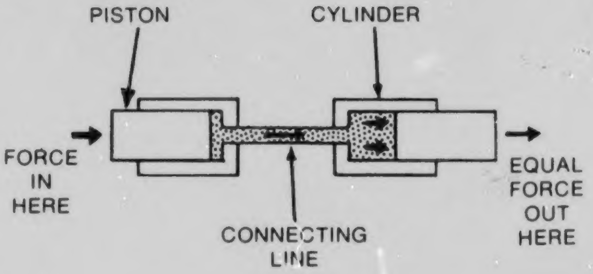


(6-179) HYDROSTATIC DRIVE IN A COMPLETE POWER TRAIN

Courtesy of John Deere Ltd.

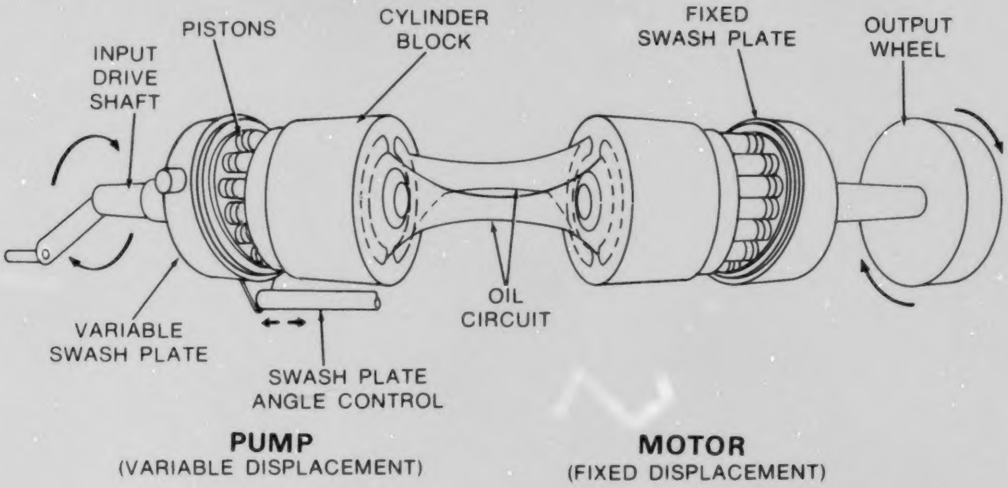
Figure 6-180 shows the principle of hydrostatic drive. Two cylinders, each containing a piston, are connected by a line. The line and parts of the cylinders contain oil. When a force is applied to the piston on the left, it moves against the oil. Fluids, as was discussed in Block 3 Hydraulics, don't compress and thus the oil travels through the line and applies a force to the piston on the right side.

In an actual hydrostatic drive, two groups of pistons are used to transmit power; the group sending the force is the pump and the group receiving it is the motor (Figure 6-181). Similar to the motor, the pump has a number of pistons arranged in a circular block (Figure 6-181).


PISTON
CYLINDER
FORCE IN HERE
EQUAL FORCE OUT HERE
CONNECTING LINE

(6-180)

Courtesy of John Deere Ltd.


INPUT DRIVE SHAFT
PISTONS
CYLINDER BLOCK
FIXED SWASH PLATE
OUTPUT WHEEL
VARIABLE SWASH PLATE
OIL CIRCUIT
SWASH PLATE ANGLE CONTROL
PUMP
(VARIABLE DISPLACEMENT)
MOTOR
(FIXED DISPLACEMENT)

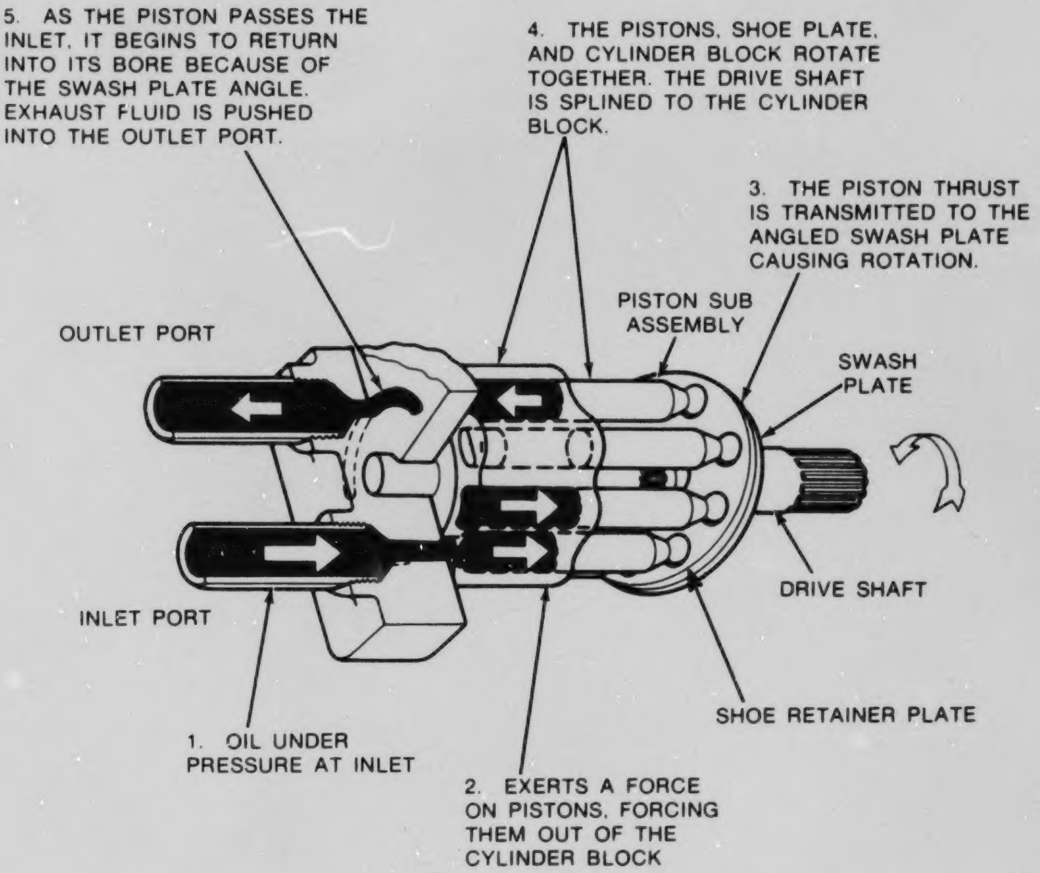
(6-181) Courtesy of John Deere Ltd

Hydrostatic Pump

The pump cylinder block is splined to the input drive shaft and rotates with it. The shaft is driven by the machine's engine and so rotates at a speed set by the operator. Pistons in the cylinder block have little rollers on the heads which run on a sloping plate called a swash plate. The swash plate is held stationary. As the cylinder block rotates, the pistons move in and out, driven in by the closest section of the tilted swash plate and out by oil pressure coming back from the motor. The piston rollers are always touching the swash plate. The workings of the circular block of pistons and the swash plate, like a planetary gear set, is difficult to grasp in words. However, once you see a dismantled pump or motor the operation will become obvious.

As the pistons are driven into the bores by their contact with the angled swash plate, they apply a force which sends pressurized oil to the motor. Thus the rotary motion of the input drive shaft is changed first to the reciprocal motion of the pistons and then to the hydraulic pressure of the oil.

The slope or angle of the swash plate can be varied so that the volume and pressure of the pumped oil varies: the greater the angle the greater the volume and pressure of oil. The angle can also be reversed so that the direction of oil flow is reversed. A pump or motor with a movable swash plate is called a variable displacement unit. A pump or motor with a fixed swash plate is called a fixed displacement unit.


5. AS THE PISTON PASSES THE INLET, IT BEGINS TO RETURN INTO ITS BORE BECAUSE OF THE SWASH PLATE ANGLE. EXHAUST FLUID IS PUSHED INTO THE OUTLET PORT.
4. THE PISTONS, SHOE PLATE, AND CYLINDER BLOCK ROTATE TOGETHER. THE DRIVE SHAFT IS SPLINED TO THE CYLINDER BLOCK.
3. THE PISTON THRUST IS TRANSMITTED TO THE ANGLED SWASH PLATE CAUSING ROTATION.
PISTON SUB ASSEMBLY
OUTLET PORT
SWASH PLATE
DRIVE SHAFT
INLET PORT
SHOE RETAINER PLATE
1. OIL UNDER PRESSURE AT INLET
2. EXERTS A FORCE ON PISTONS, FORCING THEM OUT OF THE CYLINDER BLOCK

(6-182) HYDROSTATIC MOTOR

Courtesy of Sperry Vickers, Sperry Rand Corporation

Hydrostatic Motor

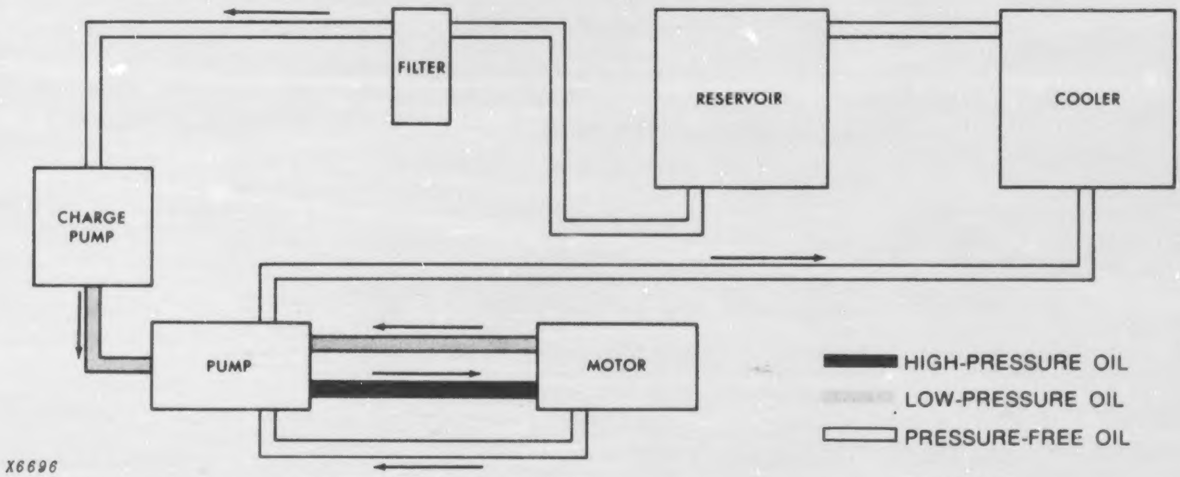
A hydrostatic motor is shown in Figure 6-182. Oil from the pump is forced into the cylinder bores through the inlet port. The force on the pistons at this point pushes them against the swash plate. They can move only by sliding along the tilted swash plate to a point further away from the cylinder barrel. In so doing, they cause the cylinder barrel to rotate. The cylinder barrel is splined to the drive shaft (the shaft passes through a hole in the swash plate), and so the shaft must turn too.

The transfer of motion that occurs at the motor is exactly opposite to what happens at the pump: incoming hydraulic pressure is converted to reciprocal motion in the pistons and then to rotary motion at the output drive shaft.

As stated earlier, swash plates in motors can be fixed or variable. A variable swash plate means that the displacement of the motor is variable and thus its speed-to-torque ratio can be changed. When the plate is at maximum angle, the displacement is maximum because the pistons travel maximum length. The motor runs slow but with lots of torque. As the angle is reduced piston travel shortens and the displacement is decreased. The motor speeds up but it has less torque. Thus, by changing the angle of the swash plate on the motor, a hydrostatic drive can give a broad range of speed-to-torque ratios.

Hydrostatic Drive System

The pump-motor is the heart of a hydrostatic drive. However, other components are needed to complete the drive's hydraulic system. A reservoir is needed to supply oil, a filter to remove dirt, and a cooler to remove excess heat from the oil. A circuit for a hydrostatic drive is illustrated in Figure 6-183.



(6-183) COMPLETE SYSTEM FOR A HYDROSTATIC DRIVE (CLOSED HYDRAULIC LOOP)

Courtesy of John Deere Ltd.

Although there is some circulation of oil through the cooler, reservoir and filter, basically the pump and motor are joined in a closed hydraulic loop. The return line from the motor goes directly back to the pump, not to the reservoir. Supply oil from the reservoir is used mainly by a charge pump to maintain oil pressure.

Types of Hydrostatic Drives

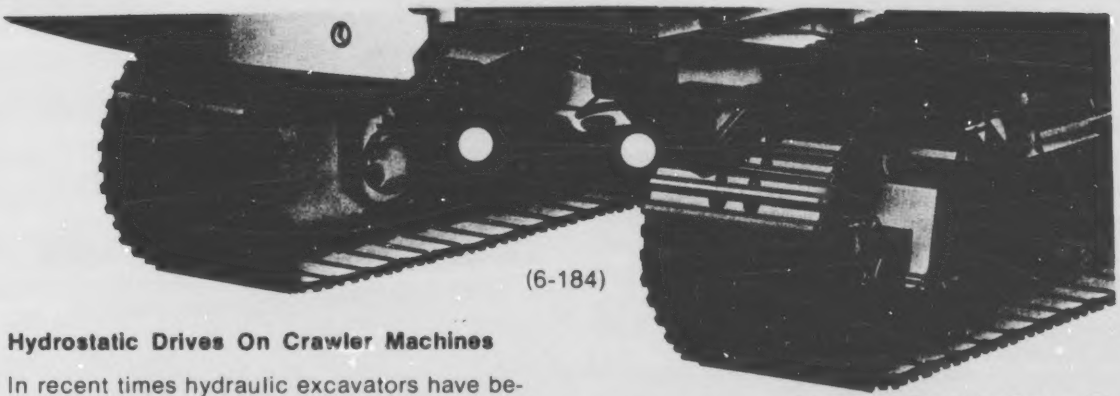
Pumps and motors are classed according to:

- — displacement size and
- — displacement type

Displacement is defined as the amount of fluid which a pump can move, or vice versa a motor can use, during each revolution. Displacement is directly related to the horsepower output of the drive. As you have already seen, pumps and motors can have a fixed or a variable displacement. Four pump-motor combinations are possible:

1. Fixed displacement pump driving a fixed displacement motor.
2. Variable displacement pump driving a fixed displacement motor.
3. Fixed displacement pump driving a variable displacement motor.
4. Variable displacement pump driving a variable displacement motor.

The fourth one is the most common arrangement used by hydrostatic drives.



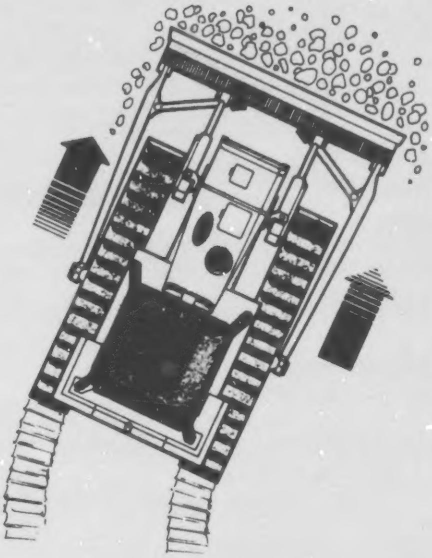
(6-184)

Courtesy of Caterpillar Tractor Co.

Hydrostatic Drives On Crawler Machines

In recent times hydraulic excavators have become very common. Hydraulic propel, that is hydrostatic drive, has replaced the mechanical propel of former excavators. Each track side of a hydrostatically driven machine has its own independently controlled hydraulic motor. This motor provides both brake and steering for the tractor. Figure 6-184 shows the lower works of a typical excavator with hydrostatic drive. The hydraulic motors are mounted to the final drive cases on the inside rear of the track frames.

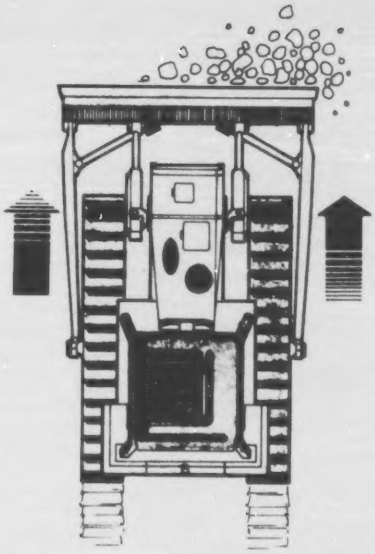
Hydrostatic drive allows for continuous and independent control of the power flow to the tracks. The tracks can be driven independently at any speed in the machine's speed range. To steer a machine with hydrostatic drive, power flow is reduced to one track; the more it's reduced the faster is the turn. For turning in tight situations power can actually be reversed in one track so that the tracks counter rotate enabling the machine to spot turn within its own length. Note that because hydrostatic steering has continuous control of power flow to a track, brakes are not needed as a turning aid but they are required in multi-disc and planetary gear steering where power can only be cut completely and the brake is needed to stop the neutral track from moving with the momentum of the machine. Figure 6-185 illustrates the steering advantages of a hydrostatic system.



(6-185)

Hydrostatic drive controls the speed and power for each track — from 0 to 6.5 mph — in forward and reverse. Thus, an infinite speed range of turns is possible.

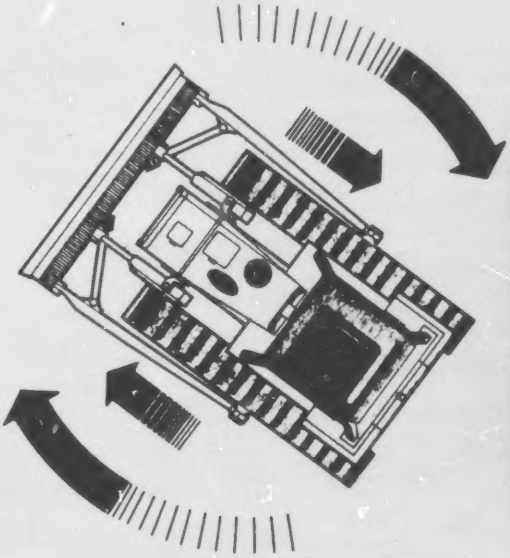
Courtesy of John Deere Ltd



(6-185)

Hydrostatic drive keeps the machine moving straight ahead even when it's corner loading the blade during a heavy cut. Resistance on the loaded side can be counteracted to give uniform traction to both tracks.

Courtesy of John Deere Ltd.

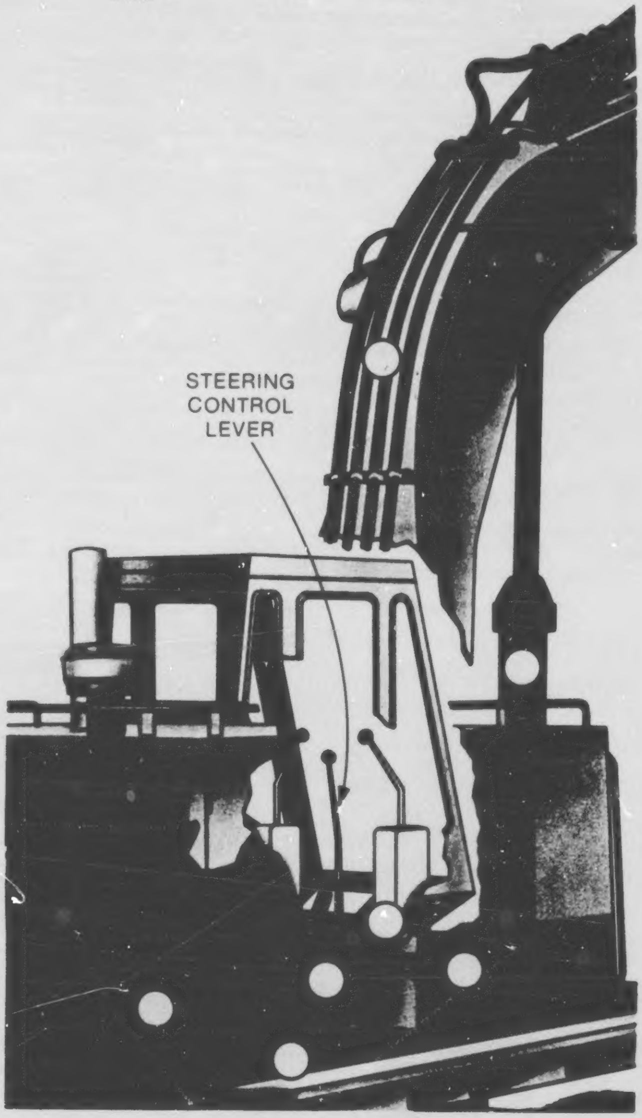


(6-185)

With hydrostatic drive the tracks can counter rotate allowing the machine to spot turn in tight quarters.

Courtesy of John Deere Ltd.

Controls for the hydraulic motors are located in the machine's cab. In Figure 6-186, the center lever is a steering control which is used in conjunction with two floor pedals, one for forward, and one for reverse. Most excavators use a system of steering controls similar to this.



(6-186)

Courtesy of Caterpillar Tractor Co.

Hydrostatic drives are not only found on excavators. Many agricultural wheeled vehicles use a hydrostatic drive. And, as was mentioned earlier, John Deere manufactures a crawler dozer and a crawler loader that have hydrostatic drive.

Controls For Multi-Disc, Planetary, and Hydrostatic Steering

The following types of controls are used on crawler steering:

- — manual
- — boosters (manual and hydraulic)
- — full hydraulic
- — electric pneumatic
- — electric hydraulic

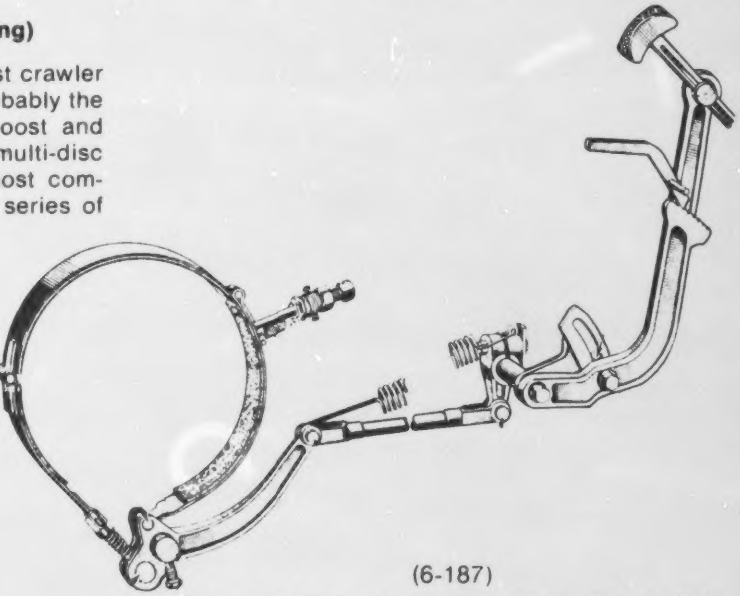
All early crawler machines had manual controls. Over the years demands for ease of control, especially on larger machines, and for less maintenance, have resulted in the development of the other four types of steering controls.

Manual Controls (Multi-Disc Steering)

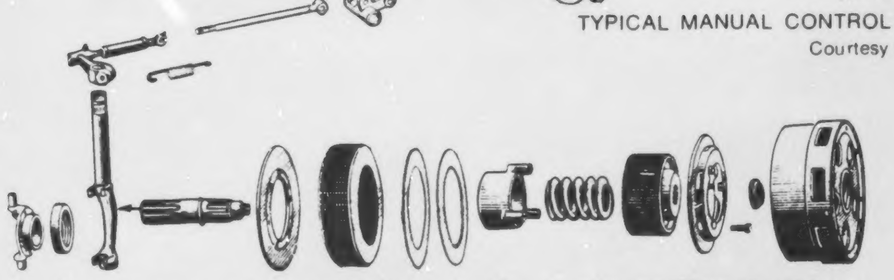
Multi-disc, although one of the oldest crawler machine steering systems, is still probably the most common. Manual, hydraulic-boost and full-hydraulic controls are used with multi-disc steering but full-hydraulic is the most common. Manual controls are simply a series of linkages that connect the clutch control lever in the cab with the clutch and connect the brake pedal with the brake bands. Manual controls are being phased out today and are used only on some small loaders and dozers. They will also be found on older machines.

Machines with manual controls have two steering clutch levers, one left and one right, both held forward in the engaged position by springs. The clutches are disengaged by pulling the levers fully back. Manually controlled machines also have two brake pedals which operate independently and are applied by depressing against spring tension. These brakes may be applied and held for parking by a lock lever.

Figure 6-187 illustrates simple manual controls for one clutch and one brake. Remember the machine will be equipped with two clutch levers and two brake pedals. Note the lock lever on the brake pedal. Threaded adjusters are located within the linkage to compensate for normal running wear. Adjustment will be covered in the Service Repair Section.



(6-187)
TYPICAL MANUAL CONTROL LINKAGE FOR BRAKE
Courtesy of International Harvester

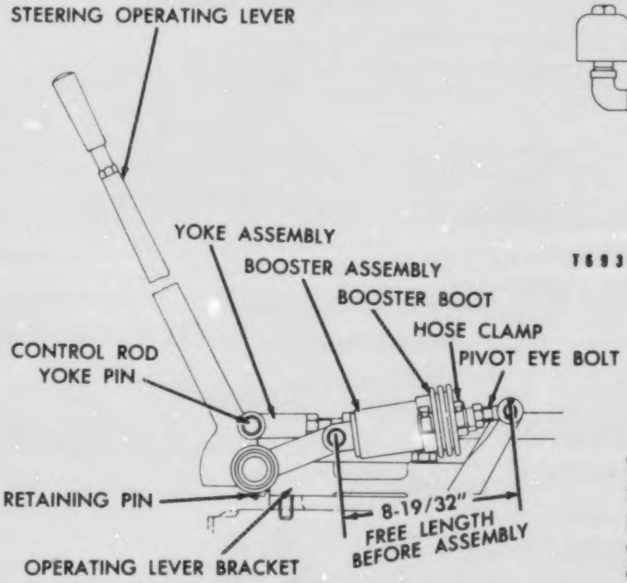


(6-187) TYPICAL MANUAL CONTROL LINKAGE FOR STEERING CLUTCH
Courtesy of International Harvester

Clutch Boosters

Mechanical and hydraulic boosters can be added to manual controls to reduce the effort required to disengage the clutch or apply the steering brakes. Boosters are generally found on large machines, but like manual controls they are being replaced by full hydraulic actuating mechanisms.

Mechanical clutch boosters are an over center, spring-loaded assembly attached to the lower end of each steering operating lever (Figure 6-188). The booster consists of a spring-loaded plunger within a cylinder; movement of the control lever causes the plunger to expand under spring pressure to assist in disengaging the clutch.



(6-188)

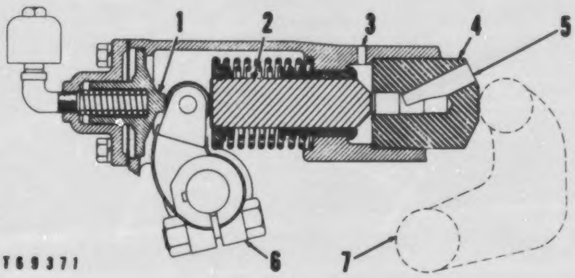
Courtesy of Fiat Allis Construction Machinery Inc.

Hydraulic clutch boosters do the same job as mechanical boosters, but instead of using spring or mechanical power they use hydraulic pressure. Movement of the control lever activates a control valve which in turn applies hydraulic pressure to the booster cylinder to aid in clutch release. In both cases a small effort on the control lever has resulted in an increased effort at the clutch yoke.

Brake boosters assist the operator in applying the brakes both to turn and to stop the machine. Hydraulic brake boosters are used on most current tractors that have contracting band brakes and full hydraulic controlled clutches. Housings for hydraulic brake boosters are located on the bevel gear case above the steering clutch compartments. A separate hydraulic booster is used for each brake.

Oil is delivered to the boosters through a flow divider. Regardless of their pressure requirements, the flow divider piston equally divides the flow of oil to both of the brake hydraulic boosters. Thus, even though one brake is being applied for a turn, there is still full pressure available at the other brake so that the machine can be safely stopped.

Oil from the flow divider is delivered by lines to the hydraulic boosters and enters the booster housings at the inlet port (3) in Figure 6-189.



(6-189)
HYDRAULIC BOOSTER OPERATION

1—Stop. 2—Valve. 3—Inlet port. 4—Booster piston. 5—Passage. 6—Lever. 7—Bellcrank.

Courtesy of Caterpillar Tractor Co.

When the brake pedal is not depressed, oil flows through the passage (5) in the booster piston (4) and is dumped into the steering clutch compartment. When the brake pedal is depressed, the lever (6) is rotated, moving the valve (2) forward and restricting the flow of oil through the booster piston (4). Oil pressure rises and moves the booster piston (4) to the right. The booster piston moves the bellcrank (7) and applies the brakes. A bumper (1) is provided for each brake to prevent damage to the hydraulic booster when the brake pedals are suddenly released.

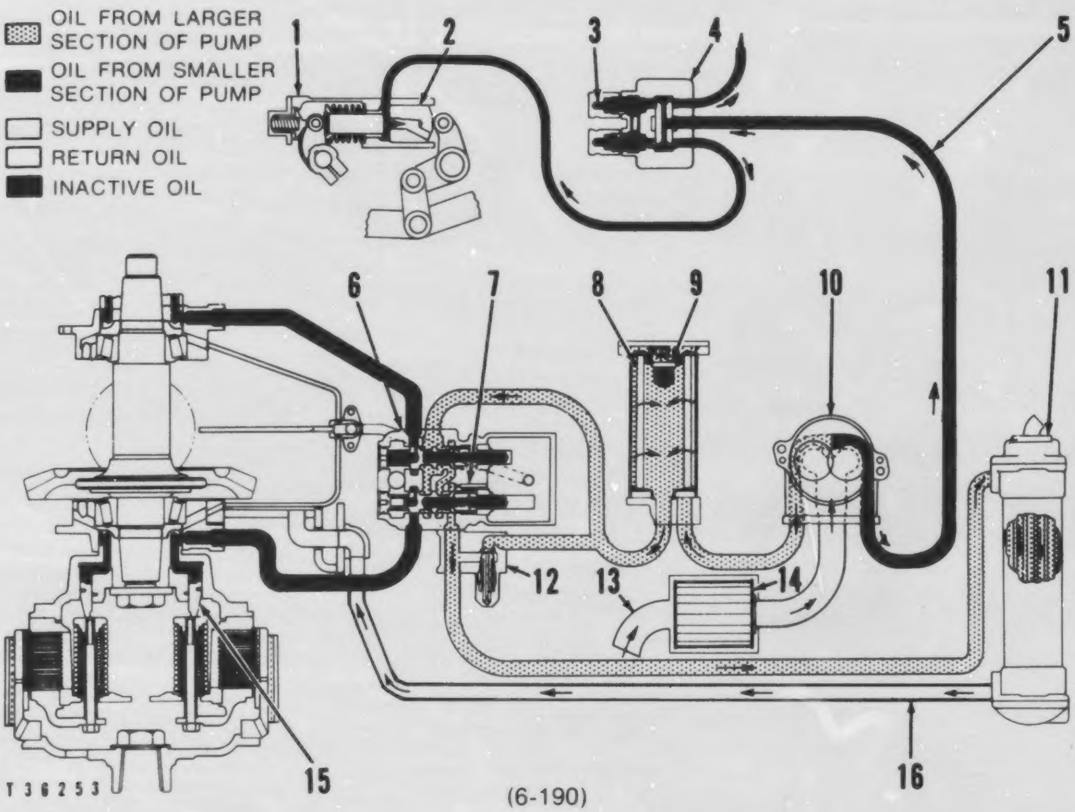
Full Hydraulic Controls

There are many different types of hydraulic controls used to operate clutches and brakes. Some of the common types are discussed below.

1. Caterpillar uses a multi-disc clutch that is spring-applied and hydraulically (full hydraulic, not hydraulic boosted) released, in conjunction with band brakes that are hydraulically boosted. When a steering clutch lever is pulled to the released position, oil under pressure is directed through the control valve to the clutch release piston (see Figure 6-172) to disengage the clutch. Releasing the control lever will dump the oil from the clutch piston, allowing the springs to engage the clutch again. Partial movement of the clutch lever will, in turn, give partial disengagement due to clutch plate slippage. Even though the clutch plates may be wet or oil cooled, such slippage or partial disengagement is not a good operating practice on a regular basis.

   Brakes are separately controlled by two pedals. When a pedal is depressed, brake application is hydraulically assisted by a booster. One pedal is depressed to aid in turning the tractor: both pedals are pushed to stop it.

   Figure 6-190 shows a Caterpillar steering system with full hydraulic clutch release and hydraulic booster brakes. Note the two section pump; in this case the large section supplies the steering clutches and the small section the brake booster.



(6-190)

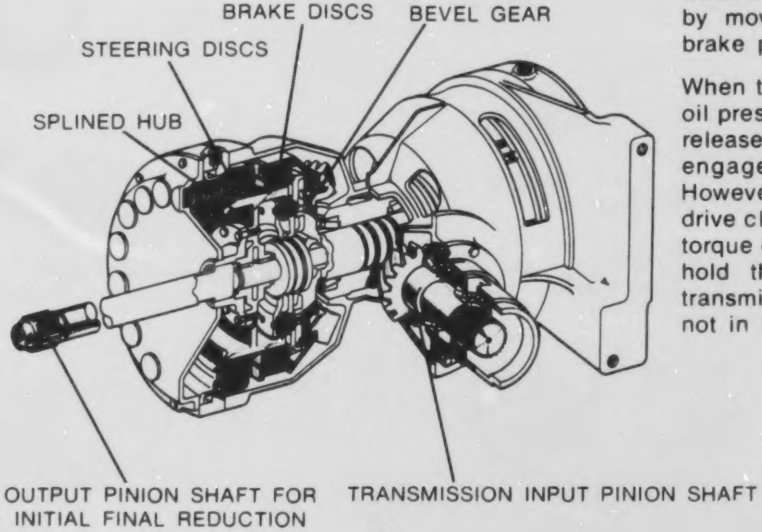
FLOW OF OIL

1—Brake booster. 2—Booster piston. 3—Pressure relief valve. 4—Flow divider. 5—Line. 6—Steering clutch hydraulic control. 7—Orifice. 8—Filter. 9—Filter by-pass valve. 10—Pump. 11—Oil cooler. 12—Steering clutch pressure relief valve. 13—Suction line. 14—Screen. 15—Piston. 16—Line.

Courtesy of Caterpillar Tractor Co.

2. Terex, also uses hydraulically controlled multi-disc clutches, but instead of band brakes they use multi-disc brakes (See Figure 6-174). The disc brakes are spring-applied when the machine is stopped. On start-up, hydraulic pressure applies the clutches and releases the brakes. Movement of one of the steering clutch control levers dumps oil from the steering clutch to release it. Further movement of the same lever will direct oil to the multi-disc brake to apply the steering brakes. The amount of brake application is proportional to the amount of lever movement. When the machine is shut down, oil pressure is released from the brake spring caging piston cavity and the brakes are automatically applied by spring pressure.

   Terex steering brakes (the brakes applied to either track to aid in steering the machine), it has just been seen, are activated by the same lever that disengages the clutches. The brakes also can be applied together by a brake pedal. The brake pedal also has another function. On the initial part of its travel an engine decelerator pedal is simultaneously depressed, decelerating the engine before the brakes are applied. Further movement of the brake pedal applies both brakes to slow or stop the machine when working on steep grades.


BRAKE DISCS
BEVEL GEAR
STEERING DISCS
SPLINED HUB
OUTPUT PINION SHAFT FOR INITIAL FINAL REDUCTION
TRANSMISSION INPUT PINION SHAFT

(6-191) STANDARD STEERING UNIT

Courtesy of Interntional Harvester

3. International Harvester uses several types of steering controls. The controls described here are their newest design used on a TD20E single speed steering drive.

   The single speed steering drive contains one drive clutch pack and one brake clutch pack for each side of the machine (Figure 6-191). The drive clutch packs are hydraulically applied and spring released whereas the brake clutch packs are spring-applied and hydraulically released. If a hydraulic failure occurs or the engine is stopped, the steering drive will automatically apply the brakes.

   When the steering levers are in the drive position, the drive clutch pack is held engaged and the brake clutch pack is held disengaged by hydraulic pressure. Power to the tracks is transmitted from the pinion shaft to the bevel gear and through the engaged drive clutch pack to the output shaft and sprocket.

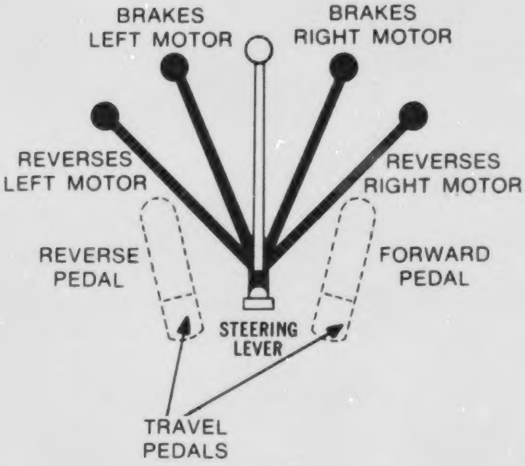
   When a steering lever is moved to the brake position, the hydraulic pressure to the clutch packs on one side of the steering drive is released. As the pressure drops, springs engage the brake clutch pack and disengage the drive clutch pack. The brake clutch pack then locks the output shaft with the steering drive housing, thereby stopping rotation of one track chain. The machine can be stopped by moving both steering levers to the brake position.

   When the foot brake is applied, hydraulic oil pressure to both brake clutch packs is released. As the pressure drops, springs engage both brakes simultaneously. However, the hydraulic oil pressure to the drive clutch packs is not released and the torque converter slips. The foot brake will hold the machine stationary with the transmission in second or third gear but not in first gear at high idle.

Hydrostatic Drive Steering Controls

There are a number of variations in hydrostatic drive steering controls. Basically, though, the controls use hydraulic pressure, either through a pilot controlled circuit or a direct controlled circuit, to modify the speed or direction of rotation of the propel motors for turning. Remember that brakes don't play a part in steering hydrostatic drive crawlers because hydrostatic drive allows for complete, continuous control of power flow to the tracks.

The operations of a steering stick and propel pedals for a hydrostatically driven Caterpillar excavator are described below. A lever mounted between the travel pedals (Figure 6-192) provides gradual pivot, or counter-rotational steering. Depress the forward or reverse pedal and move the lever toward the right or left: one track drives and the other is slowed down giving a gradual turn in the direction the lever is pushed. Move the lever farther into contact with a resistance bumper spring: one track drives and the other locks giving a pivot turn. Push the lever beyond the bumper spring and the locked track will counter rotate for a spot turn.



(6-192)

Courtesy of Caterpillar Tractor Co.

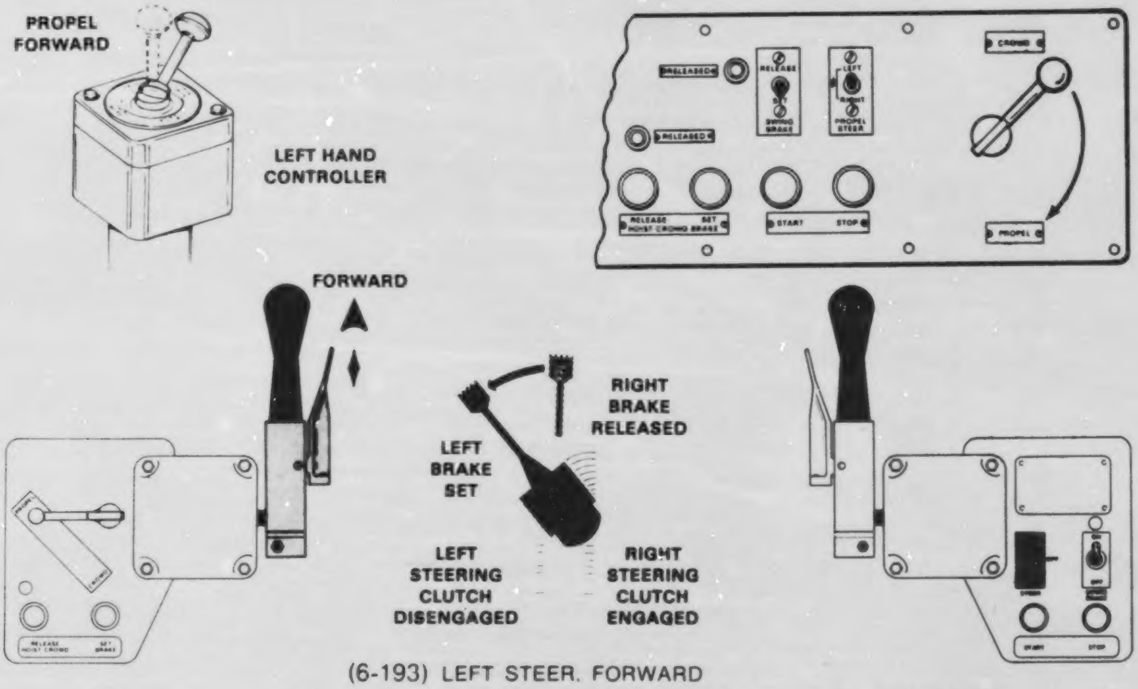
Jaw Clutch Steering Controls

Jaw clutches on shovels and cranes are usually operated by electric-hydraulic, electric-pneumatic (air), or straight hydraulic cylinders. The propel brakes on these machines are generally spring-applied and air or hydraulically released.

Below are two examples of turning procedures for machines using jaw clutches, the first for a large mining shovel and the second for an excavator.

Procedures To Forward Left Steer A P & H Mining Shovel

Left Steer: To turn left, the steering toggle switch (Figure 6-193) must be in the left steer position. Electric and pneumatic control sequencing will engage the right male jaw clutch and disengage the left male jaw clutch. This same sequencing releases the right propel brake and sets the left propel brake. To ensure that the proper jaw clutch is engaged, the operator should slowly move the excavator by moving the controller handle in the direction opposite the desired direction of travel until the excavator has moved approximately one foot. The operator should then slowly move the controller in the desired direction of travel.


PROPEL
FORWARD
LEFT HAND
CONTROLLER
RELEASED
RELEASED
RELEASE
SET
SWING BRAKE
LEFT
RIGHT
PROPEL STEER
CROWD
PROPEL
RELEASE SET
HOIST CROWD BRAKE
START
STOP
FORWARD
RIGHT
BRAKE
RELEASED
LEFT
BRAKE
SET
LEFT
STEERING
CLUTCH
DISENGAGED
RIGHT
STEERING
CLUTCH
ENGAGED

(6-193) LEFT STEER, FORWARD

Courtesy of Harnischfeger Corporation. P&H

Steering Directions For A Bucyrus Erie Excavator

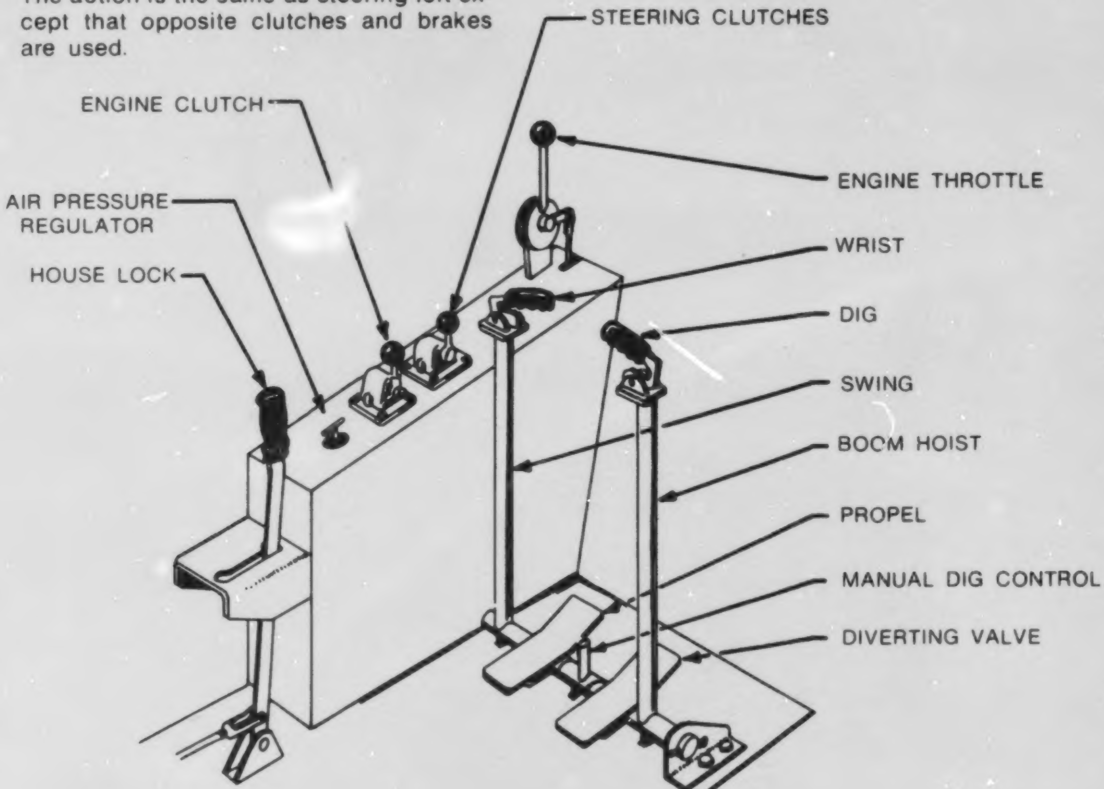
A poppet type air valve on the side valve stand (Figure 6-194) controls the steering of the machine. This valve works in conjunction with the propel foot pedal. The valve has three positions:

1. Vertical — allows for propelling straight forward or straight backward with the propel foot pedal.
2. Push forward — steer to the left by pushing down on the propel foot pedal. The poppet air valve supplies air to set the right steering clutch and to release the right digging brake. It also cuts off air from the propel foot pedal leaving the left clutch spring released and the left brake spring set. The machine will then propel around the locked left crawler belt.
3. Pull backward — steer to the right by pushing down on the propel foot pedal. The action is the same as steering left except that opposite clutches and brakes are used.

Note: — The poppet valve is spring centered to hold it in a vertical position and has detents to hold it in positions 2 and 3.

— To insure proper engaging and disengaging of the steering clutches, the propel foot pedal should be in neutral position when moving the steering clutch valve to positions 2 or 3. However, the valve handle can be returned to the neutral position while propelling in a turn, and the machine will then propel in a straight direction.

— **Always return the poppet air valve handle to the vertical position before starting to dig with machine.**



(6-194)

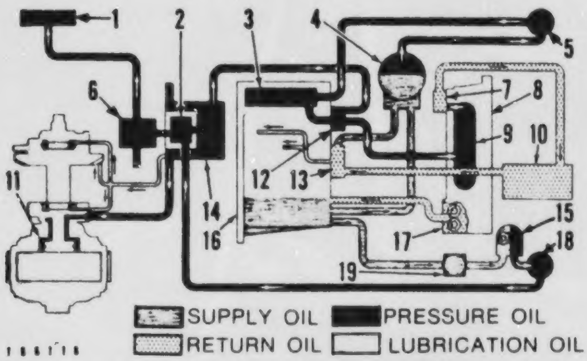
Courtesy of Bucyrus Erie Co.

BASIC LUBRICATION AND COOLING OF STEERING SYSTEMS

Most modern wet steering clutches and brakes are lubricated and cooled by oil that is part of a larger reservoir system that also supplies oil to the torque converter, transmission, and bevel gear compartment. This oil system will have one or more hydraulic pumps driven from the back of the engine or by the torque converter impeller. Pumps can be single or double section models. Often the double section models have a large section that delivers oil to the transmission and torque converter and a smaller section that pumps oil to the bevel gear and steering clutches and brakes.

A description of the circulation of oil through the oil system that includes steering clutches is given below. The numbers refer to Figure 6-195.

OPERATION



(6-195) FLOW OF OIL — SCHEMATIC

Courtesy of Caterpillar Tractor Co.

Oil is picked up by the pump (15) from the sump in the transmission case (16). Before entering the pump, the oil is drawn through the magnetic strainer (19). The oil, under pressure from the pump, is forced through the oil filter (18) to the flow control and relief valve (2). If the filter is clogged, a bypass valve in the filter housing allows oil to bypass the filter element.

The flow control relief valve (2) separates the flow of oil, directing some to the steering clutch hydraulic control valve (14) and the rest to the flow divider (6). If the oil flow becomes restricted, the relief valve will open and allow the oil to return to the torque converter inlet relief valve (12).

The oil received by the flow divider (6) is divided equally between the brake boosters (1). When the boosters are disengaged, oil flows through a passage in the booster pistons and is dumped into the steering clutch compartments. When the boosters are engaged, oil pressure is forced against the booster pistons. Two relief valves incorporated in flow divider (6), prevent pressure from becoming excessive and damaging the brake mechanism.

The valves in the steering clutch hydraulic control valve (14) direct oil to the steering clutch pistons (11) in the steering clutch hubs. These pistons move to disengage the steering clutches. If the valves should stick, the pressure relief valve unseats and the oil bypasses the steering clutch hydraulic controls. When the steering clutches are engaged oil flows around the control valves to the torque converter inlet relief valve (12). A small amount of oil is bled off through an orifice to lubricate the control valve operating mechanism and the bevel gear and bevel gear shaft bearings. Oil supplied to the torque converter inlet relief valve (12) charges the torque converter portion of the torque divider components. The scavenge pump (17) returns leakage oil from the torque divider housing (8) to the sump in the transmission case (16).

Discharge oil from the torque converter passes through the torque converter oulet relief valve (7) to the oil cooler (10) on the right side of the diesel engine. From the cooler, oil returns to the transmission lubrication regulator valve (13) where a portion of the oil is supplied to the transmission lubricating system. Oil not used for transmission lubrication is directed from the valve (13) to the inlet of the hydraulic pump (4).

QUESTIONS — TRACK MACHINE STEERING

1. List the four main steering systems used on crawler machines and give an example of the type of machine where each would be found.
2. Briefly explain how a steering clutch is used to steer a crawler machine.
3. What function do the brakes serve in crawler steering?
4. What are two types of brakes used for crawler steering?
5. List the major parts that comprise a multi-disc clutch pack.
6. What advantages do wet clutches have over dry clutches?
7. How does a single speed planetary steering system differ from a basic planetary? In a steering planetary what combination of gears is used to transmit power?
8. By what mechanism is the sun gear held in planetary steering?
9. What is the main advantage of two speed planetary steering over single speed planetary or multi-disc clutch steering?
10. Why do shovels use jaw clutches for steering rather than multi-disc clutches or planetaries?
11. How is a machine with hydrostatic drive steered?
12. Which is the most common pump-motor combination used on crawler machines with hydrostatic drive?
    - (a) Fixed displacement pump driving a fixed displacement motor.
    - (b) Variable displacement pump driving a fixed displacement motor.
    - (c) Fixed displacement pump driving a variable displacement motor.
    - (d) Variable displacement pump driving a variable displacement motor.
13. True or False. In a hydrostatic pump or motor the swash plate rotates and the circular block of pistons is held stationary.
14. Briefly list the changes of motion that take place in a hydrostatic pump and motor.
15. On a machine that has manual or booster-assisted controls, which of the following combinations of the two clutch levers and two brake pedals is used to make a pivot turn to the right?
    - (a) Both levers pulled back and left brake applied.
    - (b) Left clutch lever pulled back and right brake applied.
    - (c) Right clutch lever pulled back and left brake applied.
    - (d) Right clutch lever pulled back and right brake applied.
16. Booster controls are used to:
    - (a) Give a faster release.
    - (b) Allow bigger clutches to be used.
    - (c) Reduce the effort needed for control.
    - (d) Give smoother clutch operations.
17. On multi-disc clutches with hydraulic controls, what are the two combinations used for clutch apply and release?
18. What is the function of a flow divider for hydraulic brake boosters?
19. A machine with hydrostatic drive has ________________ steering lever and ____________ direction control pedals.
20. List the three types of power controls used for jaw clutches on modern shovels and cranes.
21. Most modern crawlers with wet clutches and brakes share a common oil supply with:
    - (a) Torque converter and final drive.
    - (b) Bevel gear compartment and final drive.
    - (c) Torque converter, transmission, and bevel gear compartment.
    - (d) Torque converter, transmission, and final drive compartment.

MAINTENANCE, TROUBLE SHOOTING AND REPAIR ON SINGLE AND MULTI-DISC AND PLANETARY STEERING

DAILY ROUTINE MAINTENANCE

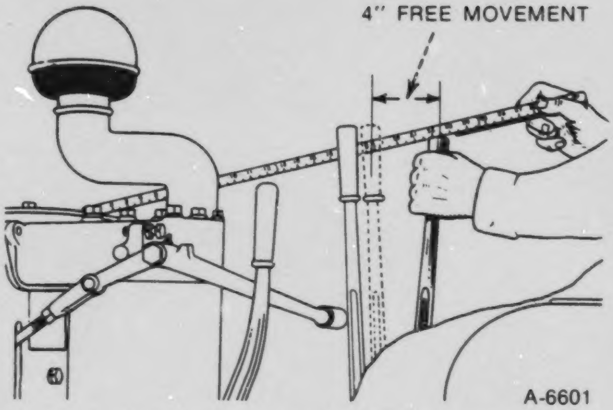
Daily routine maintenance checks for steering clutches and brakes is part of the Walk-Around-Inspection of the machine. Like final drives, steering clutches and brakes are enclosed within a housing and therefore little can be seen of them. However, there are checks and adjustments (on some machines) that can be made to ensure continued service:

1. Check the oil level on wet clutches (this check point includes the brakes usage, and add oil if needed. Should a clutch require regular topping up, further checks should be made to find the reason. Keep in mind that most wet clutch units share a common reservoir with a number of other components. Therefore, low oil in the clutch doesn't necessarily mean the problem is in the clutch; the trouble could be with one of the other components sharing the oil.
2. Some machines require adjustments on clutches and brakes to compensate for normal running wear. As was seen in the discussion of crawler steering, there are many different methods and controls for steering. Therefore, it follows that there are many ways of adjusting steering and brake mechanisms. Some of the common ones are covered here.

Multi-Disc Clutches (Manual Controls)

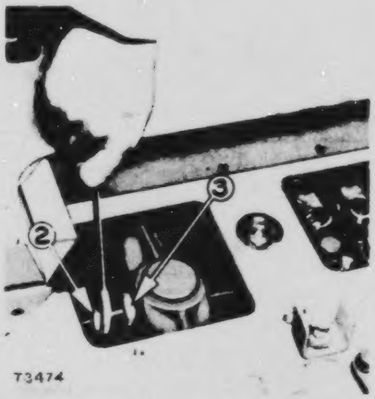
Manual controls have direct mechanical connections between the levers and the clutches and between the pedals and the brakes, making adjustment fairly simple. The need for adjustment is determined by checking lever travel on the clutch (Figure 6-196) and pedal travel on the brakes.

As the clutch multi-discs wear, the lever free travel becomes less and less, finally reaching a point where the release bearing is constantly riding. If the release bearing is left to ride, the bearing will be ruined and the clutch will slip under load.



MEASURING FREE MOVEMENT OF STEERING CLUTCH LEVERS
(6-196)
Courtesy of International Harvester

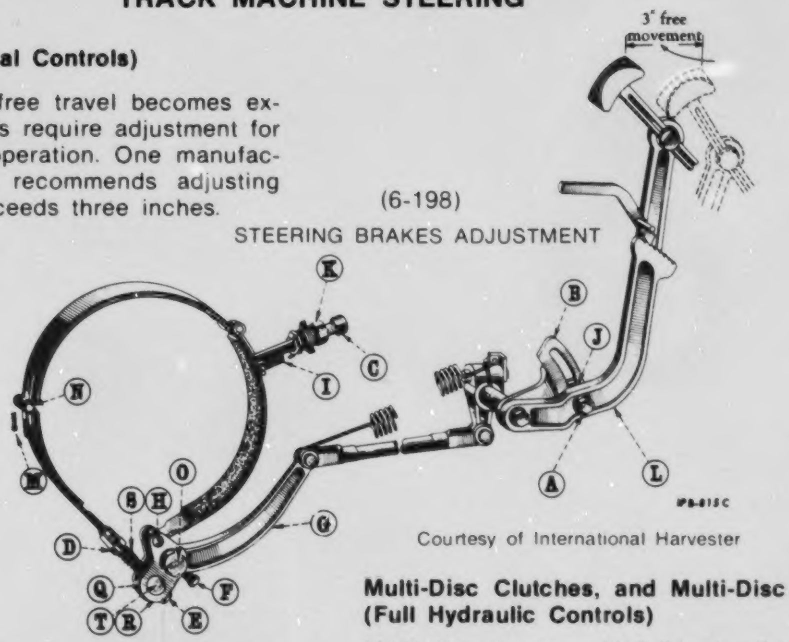
To adjust the clutches, stop the engine and find the adjusters. Some are located externally but others are found inside the steering clutch compartments, and the compartment covers will have to be removed to get at them. Consulting the service manual, adjust the clutch release bearing clearance to give the correct clutch free travel. Figure 6-197 shows an internal clutch adjustment being made.



ADJUSTING STEERING CLUTCH
2—Adjusting screw. 3—Locknut.
(6-197)
Courtesy of Caterpillar Tractor Co.

Band Brakes (Manual Controls)

When brake pedal free travel becomes excessive, brake bands require adjustment for efficient and safe operation. One manufacturer, for example, recommends adjusting when free travel exceeds three inches.



(6-198)
STEERING BRAKES ADJUSTMENT

Courtesy of International Harvester

The type of adjustments vary with the machine. Dry brakes, like the one in Figure 6-198, have two points to adjust: the brake band support screw (C) and the band adjusting bolt (E).

Refer to the machine's service manual for the number and location of brake adjusters, and for the adjusting procedures. Note: before adjusting brakes, always shut off the engine and block the machine if it is not on level ground.

Booster Aided Clutches and Brakes

Booster assisted dry, multi-disc clutches and band brakes usually are adjusted in a manner similar to manually controlled clutches and brakes. Check specific service manuals for adjusting procedures.

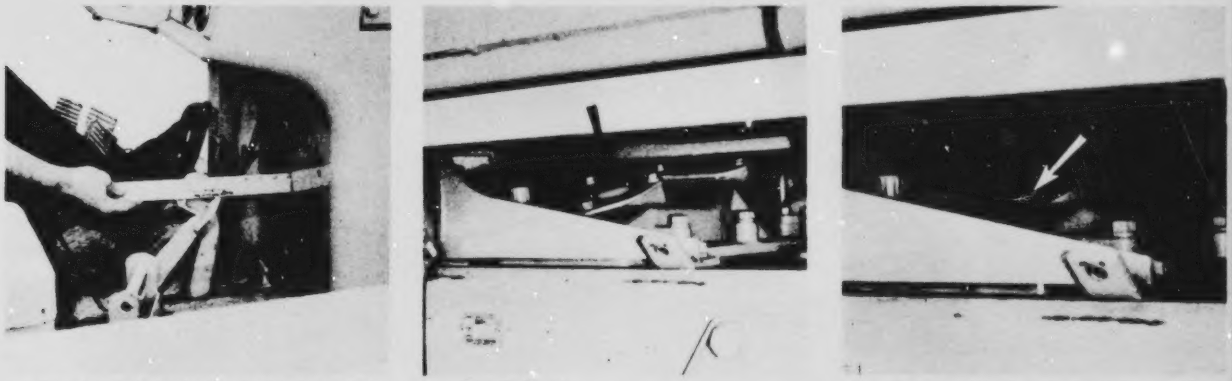
Multi-Disc Clutches, and Multi-Disc Brakes (Full Hydraulic Controls)

Multi-disc clutches with full hydraulic controls are non-adjustable, or self-compensating as they are called. No adjustment is needed because (1) they don't have a release bearing, having instead a piston and (2) the clutch units are wet which reduces wear on the clutch plates.

Like multi-disc clutches, multi-disc brakes are also non-adjustable. Thus a machine with hydraulically controlled multi-disc clutches and brakes requires very little clutch and brake maintenance.

Band Brakes (Hydraulic Controls)

Like manually controlled dry band brakes, hydraulically controlled wet band brakes require adjustment. They are easy to adjust, as seen in the example in Figure 6-199.



Check adjustment. Adjust brakes when pedal travel reaches 6 to 6-1/2 inches (160 to 165 mm).

To Adjust:

1. Remove guard and cover.
2. Turn adjusting screw in until tight. Back screw out 1-1/2 turns.

(6-199)

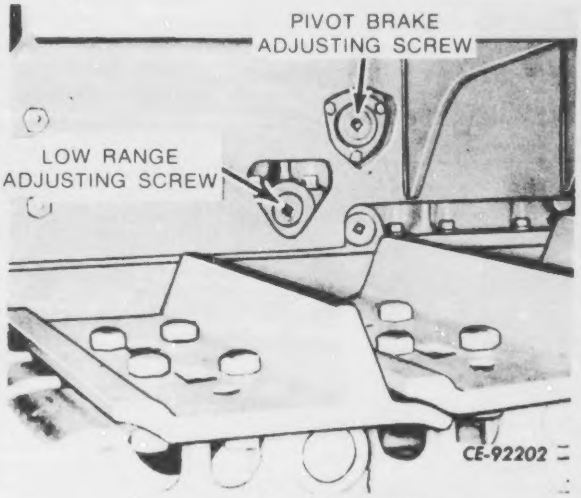
Courtesy of Caterpillar Tractor Co.

Planetary Steering and Braking (Single Disc)

Single disc planetary steering brakes and pivot brakes require periodic adjustment. When a steering brake drifts in one direction under a heavy load, it's an indicator that the brake is slipping and needs adjustment. Signs that indicate the pivot brake needs adjusting are excessive pedal free travel or slipping of the brake on turns. Access to the pivot adjuster is gained by removing a threaded plug from the side of the brake housing above the final drive case (Figure 6-200). Steering brakes have similar access holes for adjustment.

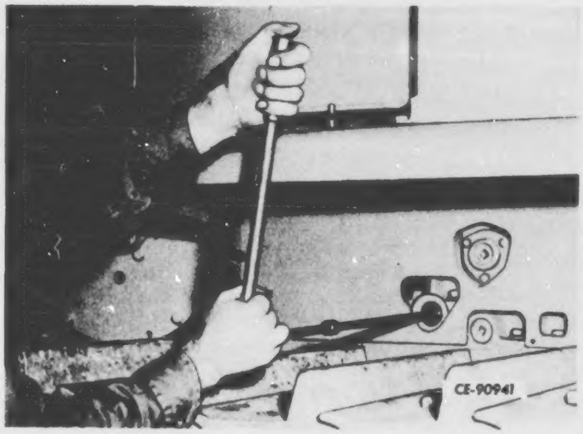
Oil Service

Steering systems usually require some type of oil service at time intervals of 50 hours, 100 hours, 250 hours, 500 and 1000 hours. The service can be anything from changing filters to draining the complete system and (1) cleaning screens (2) changing filters (3) checking screens, filters, and the sump for contamination (4) refilling. When you drain a system be sure to have a large enough container to take all the oil; some machines hold 65 gallons or more.



PIVOT AND LOW RANGE BRAKE ADJUSTMENTS

(6-200)



CHECKING LOW AND HIGH RANGE BRAKE ADJUSTMENTS WITH LOW RANGE ADJUSTING SCREW

Courtesy of International Harvester

SCHEDULED MAINTENANCE ON STEERING SYSTEMS

Scheduled Maintenance for steering clutches and brakes includes:

1. adjustment checks and procedures (if applicable)
2. oil level checks, and oil service.

Adjustments

The clutch and brake adjustment checks previously discussed can be included as part of a scheduled maintenance program. However, actual adjustments are made on an as needed basis and will often be done as a result of the daily walk-around-inspection.

Checking for contamination, as mentioned above, is a part of oil service. An example taken from a service manual of what contaminants to look for in a system that supplies oil to steering clutches and brakes is given below:

- — Iron or steel particles indicate possible transmission, transfer gear or bevel gear failure.
- — Bronze-colored particles indicate a clutch failure, either a steering clutch or transmission clutch.
- — Bright steel particles in the filter indicate a pump failure.
- — Aluminum particles indicate a torque converter failure.
- — Rubber particles indicate a blown seal or ruptured hose.

TRACK MACHINE STEERING

Following are two examples of scheduled service on crawler steering and braking.

Caterpillar D6 Crawler Dozer (only steering and braking service shown)

ITEM	SERVICE	LUBRICANT	MAINTENANCE
EVERY 10 SERVICE HOURS OR DAILY			
(9) Transmission, bevel gear and steering clutch compartment	Check oil level	S3	
EVERY 250 SERVICE HOURS OR MONTHLY			
(27) Steering clutch brakes	Check — adjust if necessary		●
EVERY 1000 SERVICE HOURS OR 6 MONTHS			
(33) Transmission, bevel gear and steering clutch compartment	Change oil and breather — wash suction screen	S3	●
EVERY 2000 SERVICE HOURS OR 1 YEAR			
(41) Brake control shaft bearings	Lubricate 2 fittings	MPG	
(42) Steering clutch control lever bearings	Lubricate 6 fittings	MPG	

Key to Lubricant:

S3 — Superior Lubricants (Series 3) only.
HYD — Superior Lubricants (Series 3) containing zinc dithiophosphate, MIL-L-2104A, MIL-L-2104B or approved Industrial-type Hydraulic Oil.
MPG — Multipurpose-type Grease
MPL — Multipurpose-type Lubricant.

Fiat-Allis Crawler Loader (only steering and braking service shown)

○ CLEAN, CHECK AND/OR ADJUST
△ HYDRAULIC CIRCUIT OIL
□ PRESSURE GUN LUBRICANT
⬯ ENGINE CRANKCASE OIL
◇ REGULAR GEAR OIL

SERVICE INTERVAL	DESCRIPTION OF SERVICE	NO. OF POINTS	TYPE OF LUBRICANT
Each 10 hours or Daily	Steering and brake linkage — lubricate	4	□
Each 100 hours or 2 weeks (Also perform 10 and 50 hour services)	Bevel gear, steering clutches and brakes — check oil level	1	
Each 500 hours or 3 months (Also perform 10, 50 and 250 hour services)	Brakes and steering clutches hydraulic system — clean filter	1	○
Each 1,000 hours or 6 months (Also perform 10, 50, 100, 250, and 500 hours services	Bevel gear, steering clutches and brakes — change oil		◇

TROUBLESHOOTING ON STEERING SYSTEMS

Introduction To Troubleshooting

No mention has yet been made of troubleshooting as a service procedure. The reason is that, generally speaking, troubleshooting requires more experience and knowledge than most first year apprentices have and it's therefore left to later training courses. However, troubleshooting should be introduced in first year, and it is done so here in relation with steering systems.

Troubleshooting is a systematic approach to locating a problem in a machine. The emphasis in troubleshooting is on applying systematic and sequential testing procedures to pinpoint a problem before attempting to make repairs. This ordered approach is used in troubleshooting to limit total repair time. The testing or checking procedures may seem time consuming, but in the long run they save time. Too often time is wasted on a hit and miss approach, disassembling components that didn't have to be taken apart if troubleshooting steps had been followed. Troubleshooting's slogan is "Test, don't guess".

The general rule in troubleshooting is to make the quickest and easiest tests first, and if nothing is found there, to proceed to the more difficult tests. Following this rule, the testing sequence would be visual checks first, then operational tests, and then instrument tests.

Troubleshooting differs from preventive maintenance in that its function is not to prevent a problem; the problem already exists and troubleshooting must find what's causing it. At the same time, though, there is a similarity between the two types of service. Troubleshooting the cause of minor problems, can often prevent much bigger and more expensive ones down the line.

Troubleshooting expertise comes from a thorough knowledge of the internal workings of components combined with lots of experience. At this level of training you should seek the help of a qualified mechanic when troubleshooting. Also, some service manuals list troubleshooting steps for different components.

Troubleshooting Steering Systems

Different troubleshooting procedures are required on the various steering systems.

Manually Controlled Clutches and Brakes

Manually operated clutches and brakes are fairly straight forward. If the various linkages operate freely, are lubricated and are adjusted to provide the correct free travel, then the problem is internal and clutches and brakes will have to be disassembled. Move, steer, stop the machine: does this give you any clues? With the help of the service manual and an experienced journeyperson, list the possible causes of the problem in the order of highest probability to the lowest before attempting any service repair.

Booster Controlled Clutches and Brakes

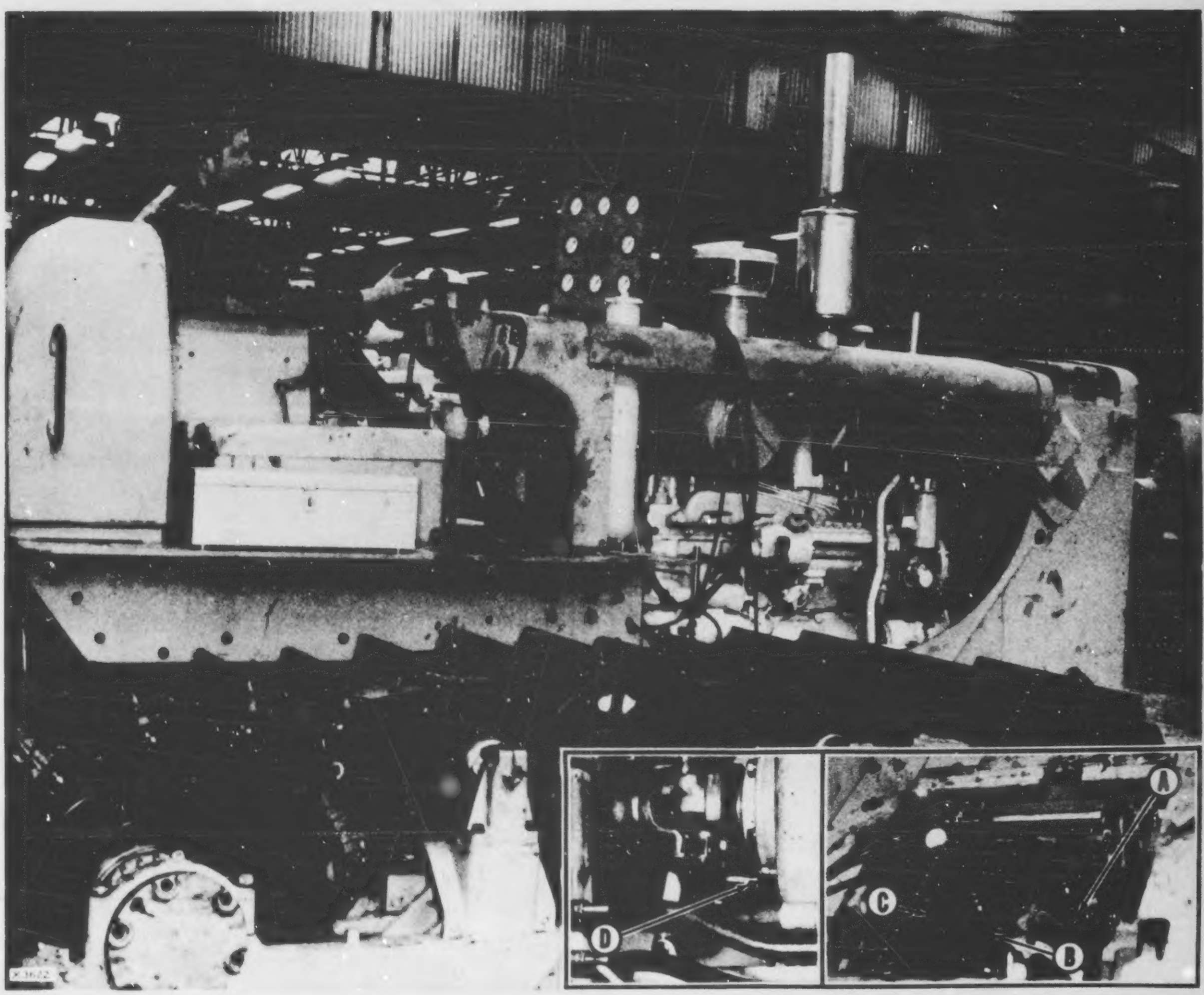
Booster Controls:

1. If the booster controls are mechanical, they can be easily checked because their workings are external and usually require only an adjustment.
2. Hydraulic booster control problems will involve some checking of valves and require a knowledge and familiarity with the hydraulic unit.

Beyond the booster controls, the system is basically the same as the manual clutches and brakes.

Full-Hydraulically Controlled Clutches and Brakes

Clutches and brakes with full hydraulic controls are probably the most complex to troubleshoot. Again you need both knowledge of how the units operate and service experience with them. The units are tested with a hydraulic test box shown in Figure 6-201.



(6-201)

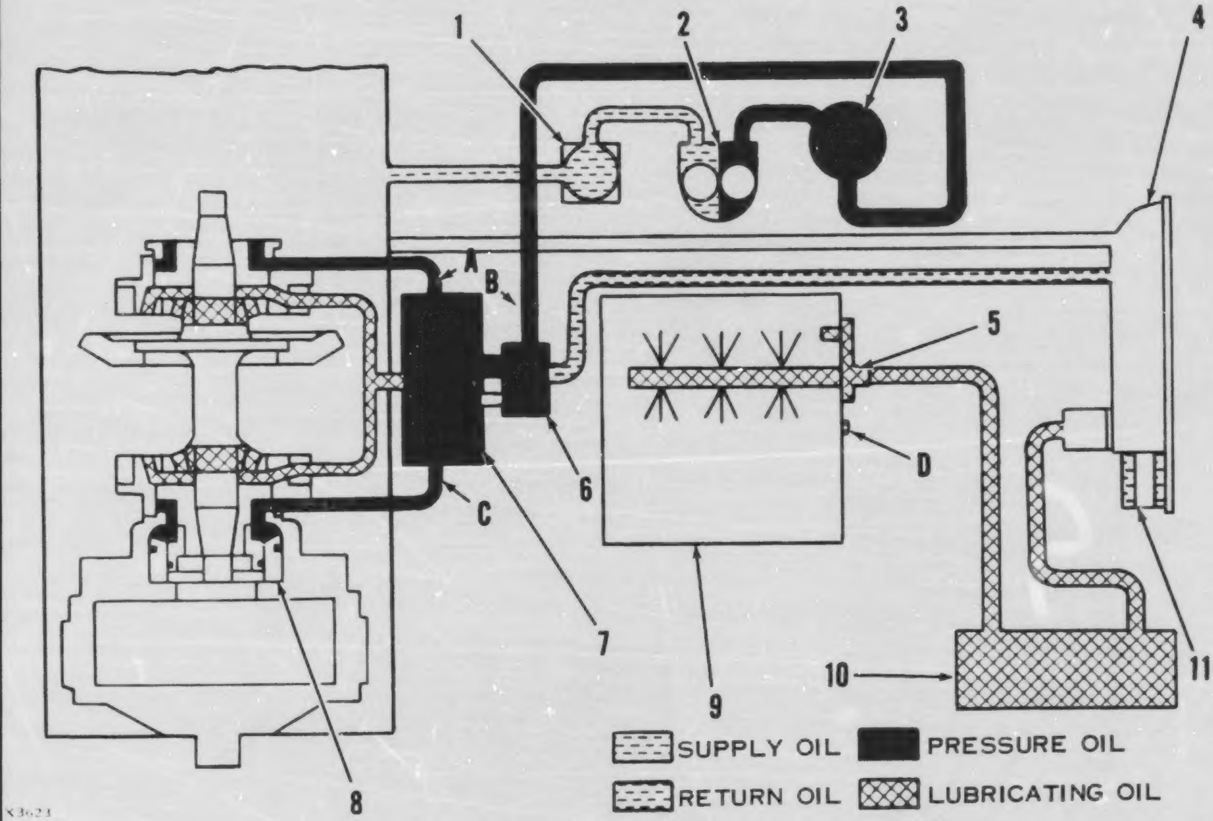
ON MACHINE PRESSURE TAP LOCATIONS

A—Left steering clutch oil pressure tap. B—Transmission oil pump pressure tap. C—Right steering clutch oil pressure tap. D—Transmission lubrication oil pressure tap.

Courtesy of Caterpillar Tractor Co.

The hydraulic test box can test the entire power train hydraulic system. Lines from the box are plugged into pressure tap locations. Readings are taken and compared to service manual specifications. If a particular unit is malfunctioning the manual will usually indicate what the problem is and what the causes are likely to be. The diagram below (Figure 6-202) shows the pressure tap locations (A, B, C, D) for the steering clutches as well as for the torque converter and transmission.

FLYWHEEL CLUTCH, TRANSMISSION AND STEERING CLUTCH HYDRAULIC TESTS



(6-202)

TRANSMISSION AND STEERING CLUTCH OIL SYSTEM — SCHEMATIC

1—Magnetic strainer. 2—Oil pump. 3—Oil filter. 4—Flywheel clutch housing. 5—Transmission lubrication regulator valve. 6—Relief valve (steering clutch hydraulic control). 7—Steering clutch hydraulic control valve. 8—Right steering clutch piston. 9—Transmission case. 10—Oil cooler. 11—Screen. A—Left steering clutch oil pressure tap. B—Transmission oil pump pressure tap. C—Right steering clutch oil pressure tap. D—Transmission lubricating oil pressure tap.

Courtesy of Caterpillar Tractor Co

Operational Checks For Steering Problems

Below are checks that Caterpillar recommends to troubleshoot steering problems on one of their machines having multi-disc clutches with contracting brake bands.

With the engine running, move the transmission speed selector lever to all positions. The detents should be felt in each position. Operate the machine in all speeds. Listen for unusual noises and determine their source. Lock the brakes and stall the torque converter in each speed. If the universal joints turn, the transmission clutches are slipping. An operational check list for steering problems follows.

Problem: Machine Will Not Turn In One Direction.

Probable Cause

1. Steering control linkage incorrectly adjusted.
2. Excessive leakage in circuit between control valve and steering clutch piston or between piston seals.
3. Valve spool stuck or valve spool spring weak or broken.

Problem: Machine Will Not Steer In Either Direction.

Probable Cause

1. Low pump output.
2. Leakage in the lines between the hydraulic system relief valve and the control valve.
3. Excessive leakage in the transmission.
4. Hydraulic system relief valve set low or leaking.
5. Incorrectly adjusted steering and brake linkage.

Problem: Machine Veers In Either Direction With Both Steering Clutches Engaged.

Probable Cause

1. Incorrectly adjusted pedal linkage.
2. Worn steering clutch plates.
3. Weak or broken steering clutch springs.
4. Broken steering clutch spring retaining bolts.
5. Worn serrations on driving and driven steering clutch drums causing plates to "hang up".

Problem: Sluggish Steering

Probable Cause

1. Incorrectly adjusted, worn or broken linkage.
2. Worn brake lining.
3. Low pump output.
4. Worn serrations on driving and driven steering clutch drums causing plates to hang up.

SERVICE REPAIR OF TRACK MACHINE STEERING

If troubleshooting procedures have indicated an internal problem in a steering clutch(es), it will have to be removed. Removing a crawler tractor's steering system is a major job, although there is a trend in modern machines towards modular components which make the removal easier. The job requires suitable lifting equipment both for personal safety and for proper care of the component.

There are some similarities common to most steering systems that can be kept in mind when removing any steering unit:

— Most steering systems have a common oil supply and the oil has to be drained.

— Steering units are all located in relatively the same place — at the rear of the tractor between the transmission and the final drive.

— Most machines require that the fuel tank, seat, hydraulic lines be removed to gain access to the clutches.

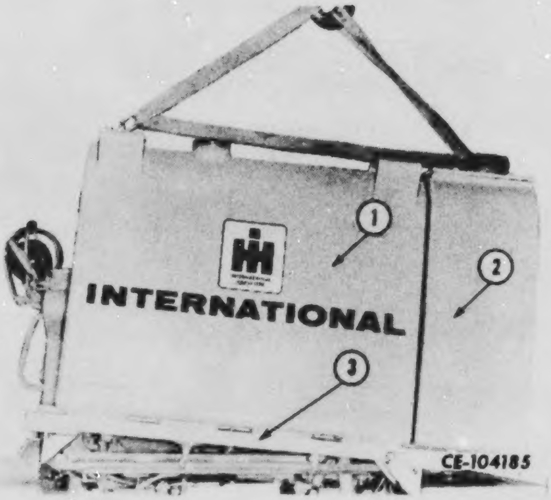
— Covers over the steering clutch compartments must be cleaned and removed.

— Removal procedures for dry clutches are the same as for wet clutches (which most modern machines have) except for the draining of oil.

— Clean practices should be maintained in removing all steering systems.

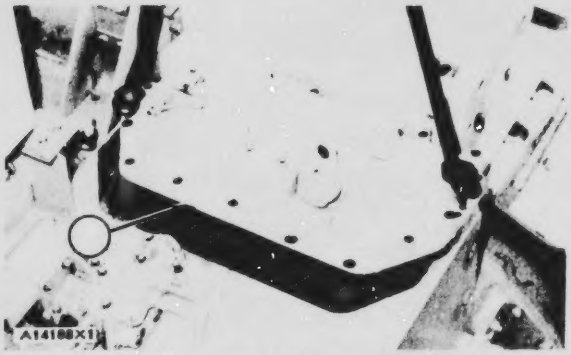
Points When Removing Steering Systems

1. Steam clean or high pressure wash the entire clutch housing area including the related parts that have to be removed. If equipment is not available the cleaning will have to be done by hand. Clean the parting faces of the housings and covers, and clean the fittings and lines before removing them. Use a wire brush to remove the bulk of the dirt and then use a bristle brush and solvent to complete the job.
2. Once the housing and surrounding area is clean, drain the oil. Be sure you have a container large enough to hold all the oil. Even though a multi-disc clutch and a band brake, such as Caterpillar uses, can be removed without draining the oil, it is a good general rule to do so. Usually when a failure occurs the oil will be contaminated and will have to be drained anyway. Note that any unit that has run in contaminated oil will have to have the inside of its housings and its screen cleaned.
3. Some steering clutches can be removed individually, but others must be removed as an assembly. In either case the clutches are disassembled after they are removed.
4. When a fuel tank has to be removed, it is not necessary to drain the tank because it will have a shut off. Be sure to cap the fuel line to prevent drain-back from the fuel filters and to protect the system from dirt. The seat may be attached to or be part of the fuel tank and can be removed at the same time. A sling, like the one in Figure 6-203, is suitable for lifting a tank. Place the removed tank in an upright position.
5. Once the fuel tank and seat are removed, disconnect the various hoses and lines, cap their ends and tag them for identification. Disconnect any linkage, unbolt the cover(s) and with suitable lifting equipment lift off the cover(s). Figure 6-204 and 6-205 show two different cover assemblies. Cat has individual covers which serve as clutch covers and brake booster assembly housings. The International shown here has a main rear frame cover; steering and brake controls are mounted on top of it. The International cover is much larger.



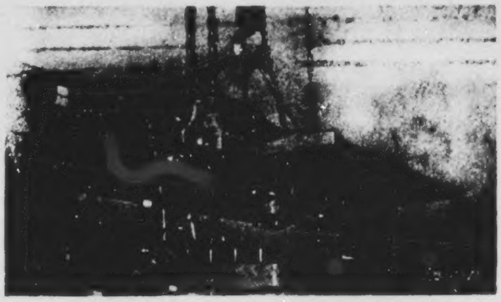
(6-203) REMOVING THE TANK AND SUPPORT ASSEMBLY

Courtesy of International Harvester



(6-204)

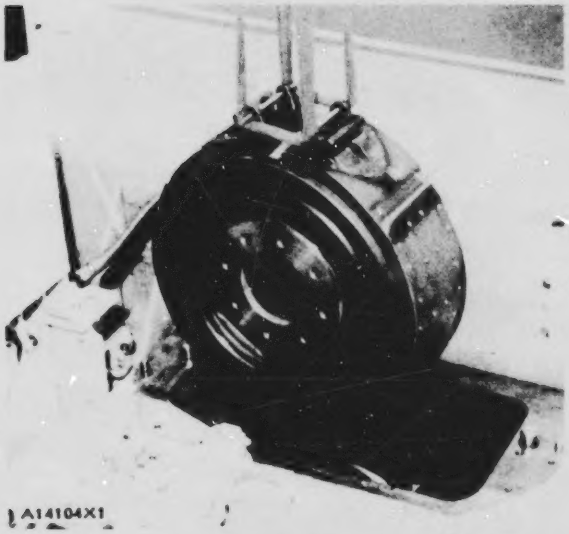
Courtesy of Caterpillar Tractor Co.



(6-205) REMOVING THE REAR MAIN FRAME COVER

Courtesy of International Harvester

6. When lifting out the steering clutch, keep the assembly level, because the clutch may slide free of the outer drum (Figure 6-206).

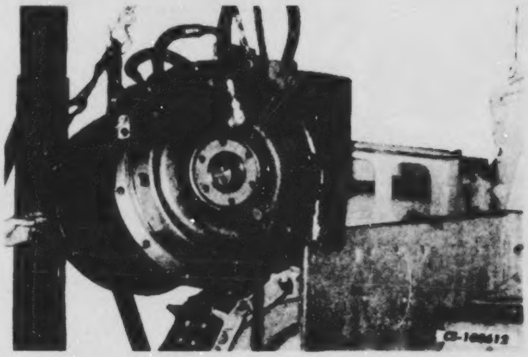


(6-206) REMOVING STEERING CLUTCH

Courtesy of Caterpillar Tractor Co.

7. Removing the planetary systems (International Harvester Tractors) is a big job on some machines because the tracks have to be disconnected and the final drives disassembled to get the pinion shaft out. The job is not as big on machines where the pinion shafts can be slid out by removing (1) a segment from the sprocket and (2) a cover over the pinion shaft outer support bearing in the final drive case.

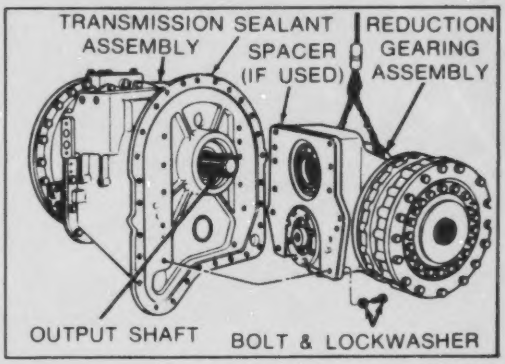
   International has recently manufactured a modular steering system that allows the clutches, brakes, bevel gear and drive pinions to come out as a unit. Provision is made to remove the output shafts from the steering drive assembly, and once the mounting bolts and various hydraulic lines are disconnected the assembly can be lift out (Figure 6-207).



(6-207) REMOVING THE STEERING DRIVE

Courtesy of International Harvester

8. Terex also uses a modular system referred to as a reduction gearing assembly. The output or quill shafts have to be removed prior to lifting out the assembly. The shafts are removed by taking off covers from the two ends of the final drive pinion shafts, similar to the removal of the International output shafts. The reduction gearing assembly and transmission are removed together and then disassembled (Figure 6-208).



(6-208)

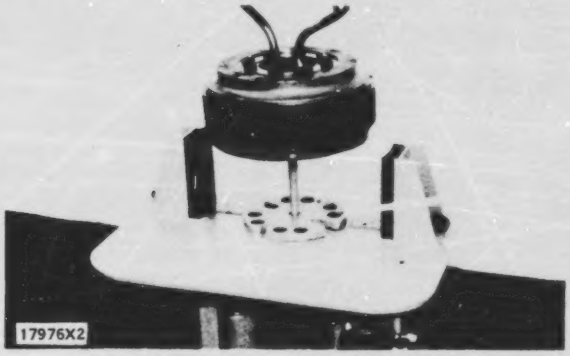
REMOVING AND INSTALLING REDUCTION GEARING ASSEMBLY

Courtesy of Terex, General Motors Corporation

Points On Disassembling and Repairing Steering Clutches

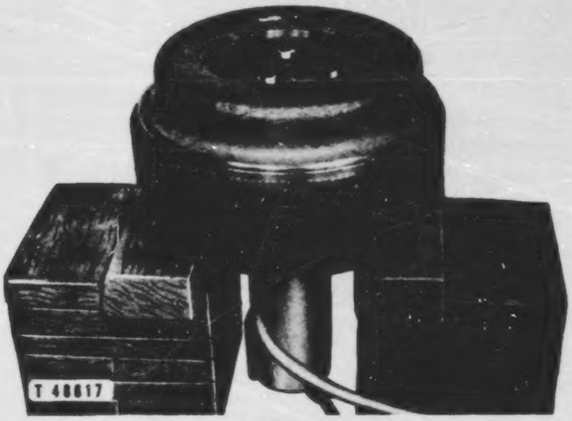
1. As was discussed earlier, there are basically two types of clutch packs: (1) spring-applied, manually or hydraulically released, and (2) hydraulically applied, spring or natural release. Spring-applied

clutches must have their springs compressed before they can be disassembled. The clutches are set into a steering clutch stand (Figure 6-209) or blocked, and then disassembled with the aid of a compressor tool or a hydraulic press.



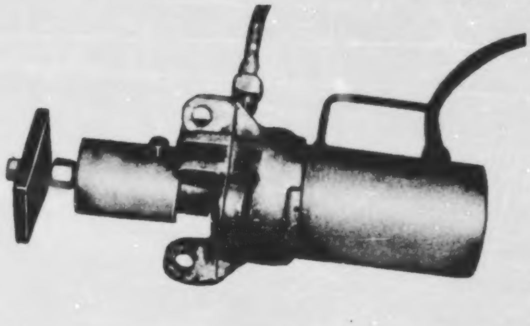
(6-209) STEERING CLUTCH STAND

Courtesy of Caterpillar Tractor Co.



(6-209)
COMPRESSING STEERING CLUTCH SPRINGS

Courtesy of Caterpillar Tractor Co

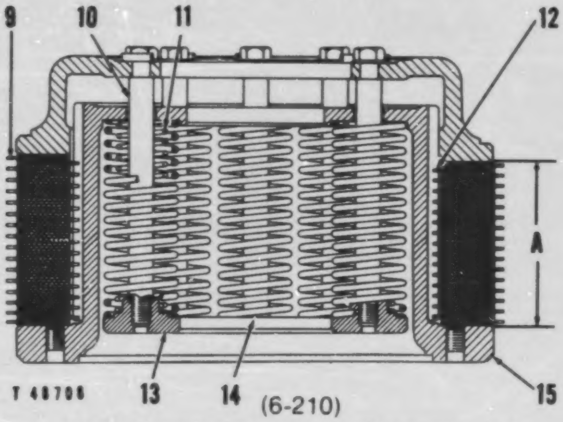


(6-209) STEERING CLUTCH SPRING COMPRESSOR TOOL

Courtesy of Caterpillar Tractor Co

2. Inspect the brake band; it may require relining.

3. A measurement is taken of the clutch pack to determine its remaining service life. The distance "A" (the stacked height) in Figure 6-210 is taken and compared to minimal standards in the service manual. Even if the clutch pack is within specifications, the discs should be checked for warping or wear on the splines. Keep the discs in the same order. Note that individual discs are not usually replaced on clutch packs, rather the pack is replaced as a whole.



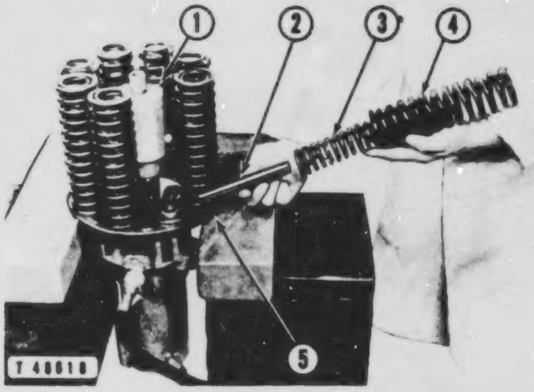
(6-210)
CROSS-SECTION OF STEERING CLUTCH ASSEMBLY

9—Disc Assembly. 10—Sleeve. 11—Inner Spring. 12—Disc. 13—Retainer. 14—Outer Spring. 15—Inner drum. A—Dimension to be checked.

Courtesy of Caterpillar Tractor Co.

4. Make the following inspections:
   (a) Check the splines on the inside of the brake drum and the outside of the drive hub, and replace them if they are worn.
   (b) The outside of the brake drum can be turned on a lathe. Since turning requires a special lathe and an experienced hand, the drums are usually sent out to be done. The important point to remember about turning drums is to be sure that they can be turned by checking minimal drum thickness requirements in the service manual. Don't make downtime longer by sending out drums that are worn too thin to be turned.

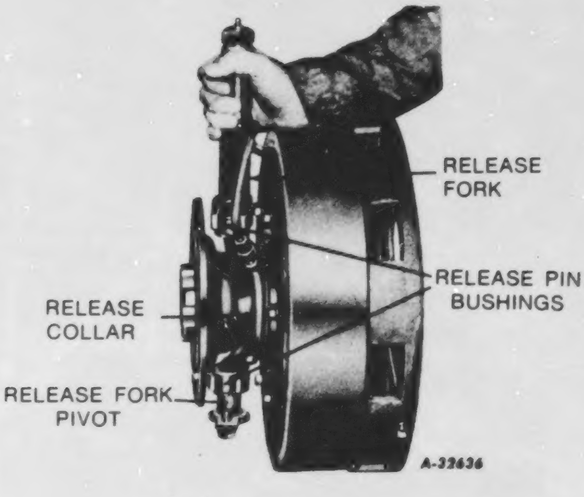
(c) Remove springs (Figure 6-211) and check them for cracks, free height and compressed height (see service manual).



(6-211)
1—Adapters. 2—Sleeve. 3—Spring. 4—Spring. 5—Retainer.
Courtesy of Caterpillar Tractor Co.

5. Check the clutch controls:

(a) Manual: the release bearing and its related parts — release pin bushings, pivot bushings, release collar thrust bearing (Figure 6-212) — must be inspected and replaced (if necessary).

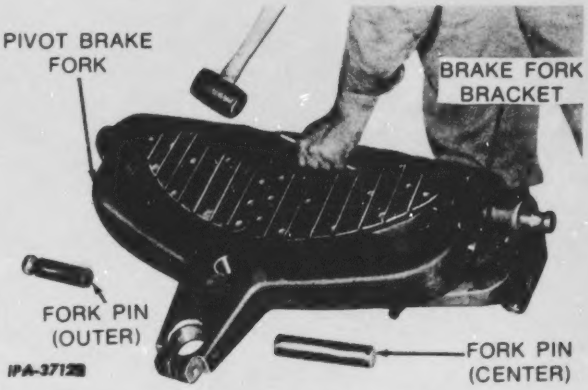


(6-212) RELEASE FORK
Courtesy of International Harvester

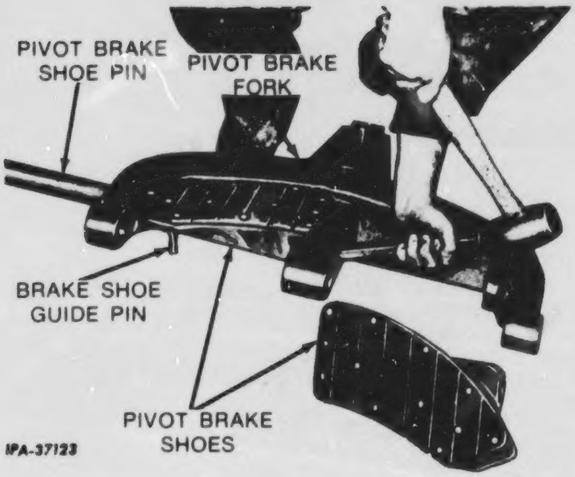
(b) Hydraulically released: the piston in the clutch hub should be removed, the bore checked and the seal replaced. The piston can be pulled from the hub with a two-jaw puller using reverse jaws.

6. Hydraulically applied clutches and brakes are generally found on modular steering systems. Unlike the previously discussed spring-applied clutches which could be repaired in the field, hydraulic applied clutches are usually disassembled and repaired in a shop. Special tools and a clean place to lay out the numerous parts are necessary when overhauling one of these units. Once it's apart, the kinds of repairs required on a hydraulically applied clutch pack are similar to the repairs on a spring-applied clutch pack.

7. One repair that may be needed on large tractors with two speed single disc planetaries and caliper brakes is to replace the linings on the caliper brake shoes. This job can be done without draining the oil. The rear main cover is removed to get at the brake assemblies and they're removed from the machines. Figure 6-213 illustrates removing the caliper shoes with a mallet and drift.



(6-213) REMOVING THE PIVOT BRAKE FORK
Courtesy of International Harvester


PIVOT BRAKE SHOE PIN
PIVOT BRAKE FORK
BRAKE SHOE GUIDE PIN
PIVOT BRAKE SHOES
IPA-37123

(6-213) REMOVING THE PIVOT BRAKE SHOES
Courtesy of International Harvester

As was mentioned earlier, any problems within the planetary gears require that the oil be drained and the whole planetary assembly be removed. Service repair on a planetary would be carried out in the same way as that for any gear component (see the service points discussed for final drive gears). Consult the service manual for planetary service repair procedures.

QUESTIONS — CRAWLER STEERING MAINTENANCE AND REPAIR

1. On a particular machine the oil supply for wet, multi-disc clutches needs frequent topping up. Does this indicate a problem with the clutches?
2. What adjustments are required for the clutches and brakes on a current machine that has full-hydraulic controlled multi-disc wet clutches and band brakes?
3. There are two types of steering and pivot brakes on planetary steering systems: single-disc and multi-disc. Do they require adjustment?
4. Briefly describe the term troubleshooting.
5. What instrument is used to test hydraulic steering controls?
6. When overhauling a multi-disc clutch assembly, what method is used to determine the service life left in the discs?
7. Spring-applied, multi-disc steering clutches have to have their springs ______ ______________________________ with a __________________ before they can be disassembled.
8. List the other things that should be checked on a multi-disc clutch at the same time that the stack of discs is measured.
9. For what reasons is it recommended to overhaul modular steering systems in a work shop and not in the field?

ANSWERS — TRACK MACHINE STEERING

1. — Multi-disc clutch — crawler loaders or dozers
   — Planetary gear — crawler loaders or dozers
   — Jaw clutch — shovels, log loaders, cranes
   — Hydrostatic — excavators and other hydraulic propel machines
2. Disengaging a steering clutch interrupts the power to one track. With power cut to one track, the driven track turns the machine toward the side with no power.
3. The brakes can be independently applied to retard or stop the movement of the drive shaft that leads to the sprocket and tracks, preventing the track from moving freely with the momentum of the machine. When a clutch-brake turn is made, the machine can make anything from a gradual turn to a sharp turn depending on the amount of brake application.
4. — Band brakes
   — Multi-disc brakes
5. — A splined inner drum (the drive member)
   — A splined outer drum (the driven member)
   — A set of alternating internally and externally splined discs
6. Wet clutches engage more smoothly than dry clutches, run cooler and last longer.
7. A basic planetary has a ring gear around the outside of the planet carrier. A steering planetary has no ring gear, but instead uses the sprocket drive pinion shaft gear which runs on the inside of the planet carriers.

   To transmit power, the sun is held, the carrier is powered, and the sprocket drive pinion shaft gear is driven.
8. A steering brake holds the sun gear. (Note that the steering brake can be called a clutch brake, a clutch control or a clutch.)
9. On single speed planetary and multi-disc clutch steering, power is cut to one track on turns. Two speed planetary steering has the advantage that power can be transmitted to both tracks (one track in high, the other in low) during a gradual turn.
10. Since travel distances for shovels is generally short, their movements slow and turns few, they can use the simpler jaw clutch for steering.
11. Machines with hydrostatic drive have separate power controls for each track. The machine is turned by reducing the power to one track; the more it's reduced the faster is the turn.
12. (d) Variable displacement pump driving a variable displacement motor.
13. False. The block of pistons rotate and the swash plate is stationary.
14. Rotary motion at the input drive shaft -to- reciprocal motion of pump pistons -to- hydraulic pressure -to-reciprocal motion of motor pistons -to- rotary motion of output shaft.
15. (d) Right clutch lever pulled back and right brake applied.
16. (c) Reduce the effort needed for control.
17. — Spring apply, hydraulic release
    — Hydraulic apply, spring release
18. The flow divider directs the flow of oil equally between both boosters so that when one brake booster is being applied there is still full pressure available at the other.
19. . . . one . . . two . . . .
20. — Electric Hydraulic.
    — Electric Pneumatic.
    — Straight Hydraulic.
21. (c) Torque converter, transmission, and bevel gear compartment.

ANSWERS — CRAWLER STEERING MAINTENANCE AND REPAIR

1. Not necessarily. The clutches share a common oil supply with other components and the trouble could be with one of these.
2. The clutches require no adjustment because they are self-compensating. The brakes require periodic adjustment.
3. Single-disc do, but multi-disc don't.
4. Troubleshooting is applying systematic, sequential testing procedures to pinpoint a problem before attempting to make repairs.
5. A hydraulic test box.
6. Measure the height of the stack of discs and compare the measurement to the specifications in the service manual.
7. . . . compressed . . . compressor tool . . . .
8. Check:

   — Splines for wear inside of the brake drum and outside of the drive hub.

   — Steel discs for warping, scores and worn splines.

   — Springs for cracks, free height and compressed height.

   — Wear on outside of the brake drum.
9. — Lack of adequate cleaning equipment.

   — Complexity of disassembly and assembly requires a clean work area.

   — Need for special tools.

TASKS — TRACK MULTI-DISC STEERING SYSTEM

ROUTINE MAINTENANCE CHECKS

Start a machine with multi-disc steering and operate the clutch and brake controls. Make any necessary adjustments. Report any more serious malfunctioning to a journeyperson.

SCHEDULED MAINTENANCE CHECKS

Following procedures from the service manual:

1. Remove and clean the oil filter housings.
2. Install new filters and gaskets.
3. Remove and clean screens and magnetic filter (if equipped).
4. Top up the oil level and run the engine to ensure there are no leaks.

TROUBLESHOOTING

If a machine is available with a clutch or brake problem, under the assistance of a journeyperson, perform troubleshooting procedures outlined in the service manual to locate the problem.

SERVICE REPAIR

Using the correct tools, equipment and procedures as outlined in the service manual:

1. Clean and remove the housing cover and remove the steering clutch and steering brake unit of a crawler loader or dozer.
2. Disassemble, clean, inspect the clutch and brake parts for wear and damage. Write a service report and parts list, and repair or replace parts that are not serviceable.
3. Reassemble the steering clutch and the steering brake.
4. Install and adjust (if applicable) the brake and clutch.
5. Check the drive train hydraulic oil level and fill to the required level with the recommended oil. Change the filter (if equipped).
6. Test the operation of the brake and clutch controls and inspect the unit to ensure it has no leaks.

BLOCK

6

Wheel Machine Suspension

WHEEL MACHINE SUSPENSION

PURPOSE OF WHEEL SUSPENSION

On wheeled vehicles the term suspension refers to the frame and all the components attached to the frame that support the machine. The purpose of suspension is to:

1. Support the machine including the power train components that drive the machine.
2. Support the steering axles (on some machines).
3. Provide a cushion to absorb shocks between the wheels and the load (on machines with springs or suspension cylinders).
4. Provide floatation.

Although there are a number of different suspension systems, they can be divided into two general categories:

— Rigid suspension.

— Spring suspension

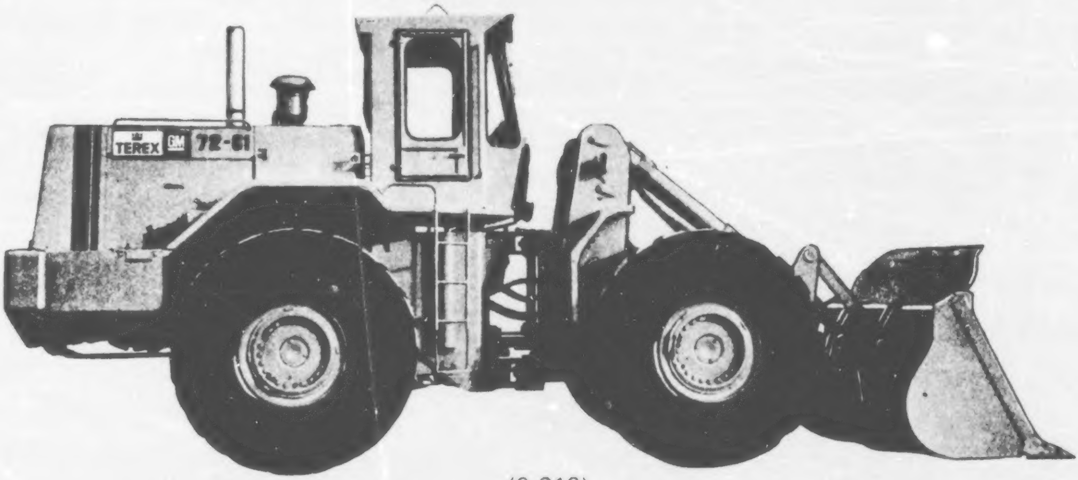
Rigid Suspension — is generally found on slow moving equipment such as graders, loaders, skidders and farm tractors. This suspension has no resilience other than the flexing of the tires. Shock loads are imposed directly on the frame and frame components. Rigid suspension gives machines good stability while travelling over rough terrain.

Spring Suspension — on the other hand, is used primarily on faster moving vehicles such as trucks. Springs or other cushioning devices are fastened between the axle housings and the frame. They support the vehicle's weight and at the same time permit an independent up and down movement of the wheels and axle housings as the wheels encounter irregularities in the road. Spring suspension also provides a smooth ride for the operator and reduces shock loads on the frame and frame components.

RIGID SUSPENSION

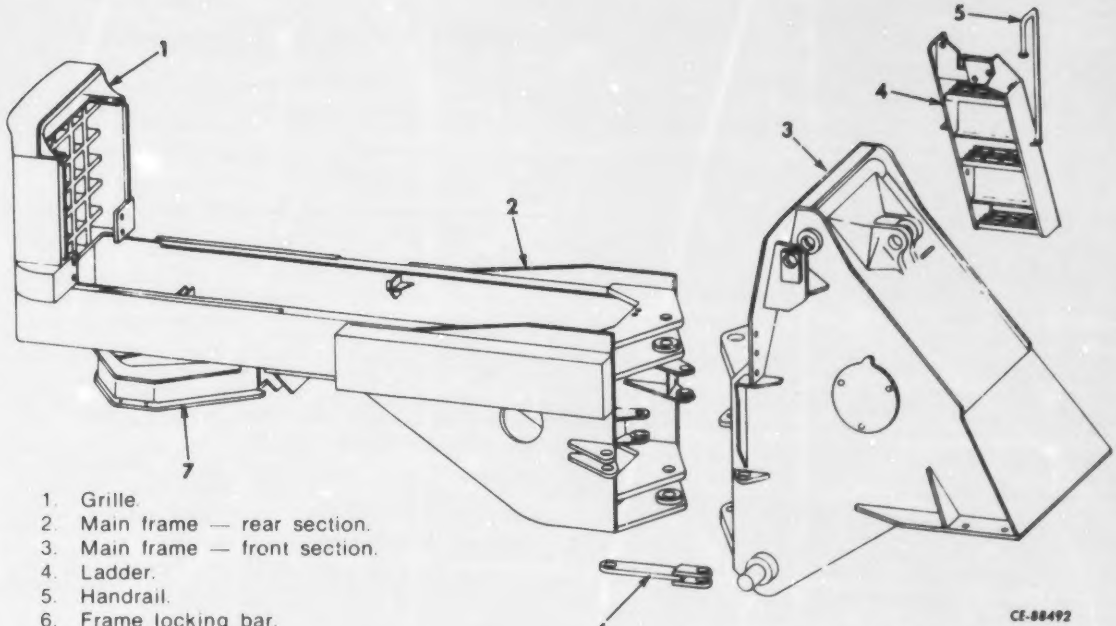
Wheel Loader

Figure 6-213 shows a four wheel drive loader with rigid suspension and articulated frames. Figure 6-214 shows a typical articulated loader frame assembly. The loader's main frame consists of a front and a rear section connected together by a pin and bearing assembly.



(6-213)

Courtesy of Terex. General Motors Corporation



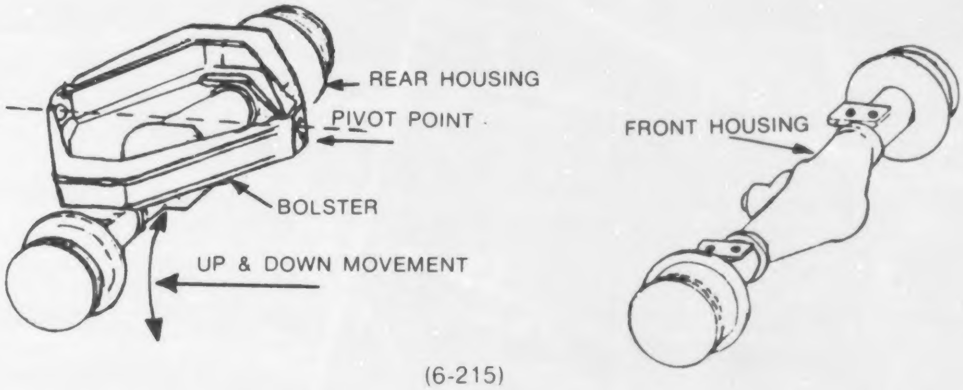
1. Grille.
2. Main frame — rear section.
3. Main frame — front section.
4. Ladder.
5. Handrail.
6. Frame locking bar.
7. Bolster.

Courtesy of International Harvester

(6-214) MAIN FRAME ASSEMBLY

Each main frame has many smaller sections welded to it and is called a fabricated frame assembly. This particular model has a grill bolted or welded to the rear section. Note the frame locking bar (6) used to lock the two frame halves together when the tractor is serviced or transported.

To complete the suspension assembly, one axle (Figure 6-215) is bolted to the front frame section, and one is bolted to a bolster or as it's sometimes called, a walking beam (7), which is attached to the rear frame section at two points by pins and bushings. The purpose of the bolster is to allow an up and down seesaw movement (oscillation of the rear axle in order to give full wheel contact with the ground when the machine is working uneven terrain (Figure 6-216). This rigid suspension system used by wheel loaders gives the machine more strength and stability than could be obtained from spring suspension.



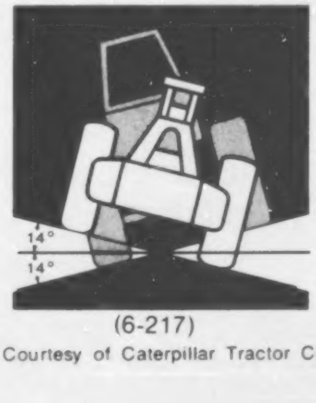
(6-215)

Courtesy of Clarke Equipment Company

(6-216)

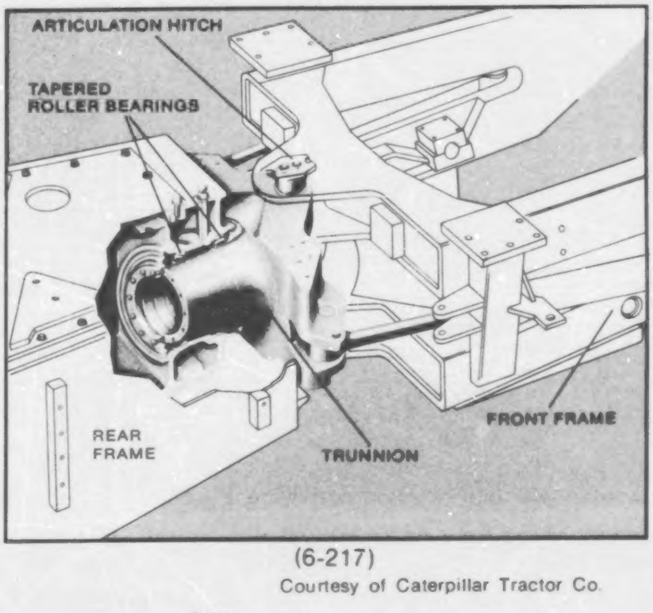
Courtesy of Terex. General Motors Corporation

An alternate system to the bolster for axle oscillation is an oscillating trunnion (Figure 6-217) used by Caterpillar. The large trunnion extends from the articulation hinge into the rear frame and is supported by two tapered roller bearings. The trunnion allows the frames to move independently of one another and still be hinged for steering.



(6-217)

Courtesy of Caterpillar Tractor Co.

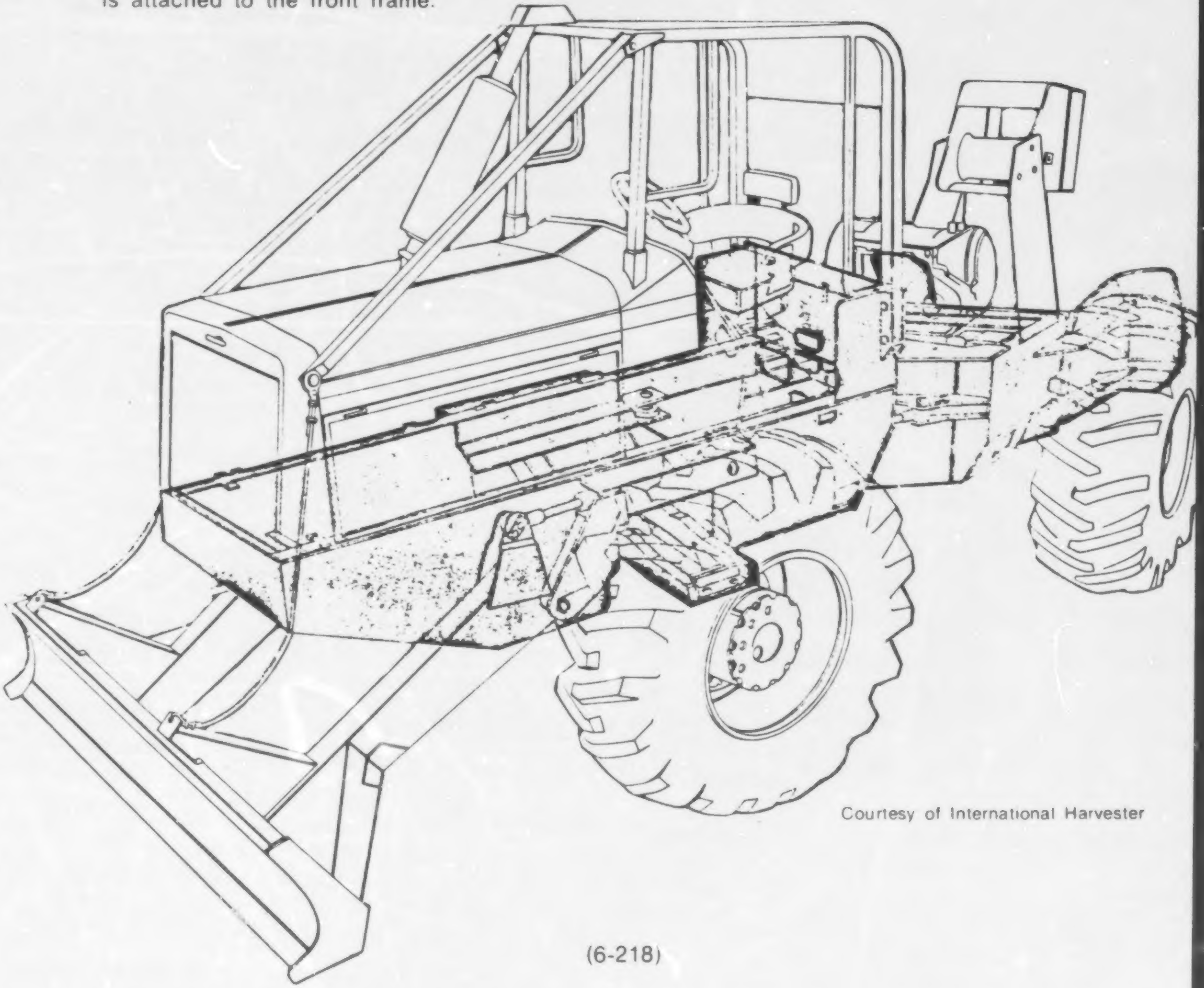

ARTICULATION HITCH
TAPERED ROLLER BEARINGS
REAR FRAME
TRUNNION
FRONT FRAME

(6-217)

Courtesy of Caterpillar Tractor Co.

Skidder

Like the frame on a loader, a skidder frame (Figure 6-218) is made of fabricated steel and is joined by a pin(s) and bushing(s) at the hinge point between the two frames. However, the skidder differs from the loader in that the long section with the engine and transmission is forward and the short section is at the back. Also, the bolster or walking beam on a skidder is attached to the front frame.



Courtesy of International Harvester

(6-218)

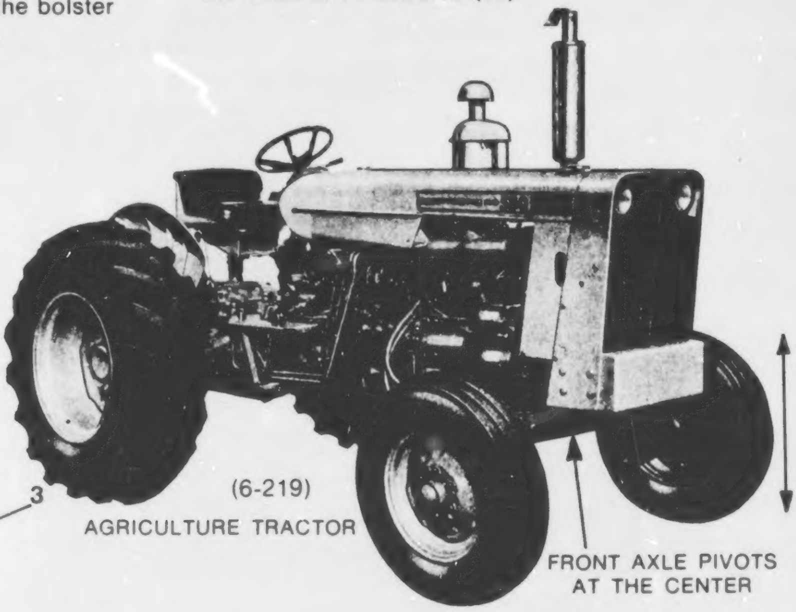
Loader Backhoes

Machines that have either front or rear axle steering, such as a loader backhoe, also have rigid suspension. Loader backhoes vary in size from small agriculture tractors with loader backhoe attachments to much larger, heavier machines made specifically for backhoeing. Loader backhoes generally have two wheel drive and front axle steering.

Loader backhoe frames are made of one piece fabricated steel. The power train and drive axle are rigidly bolted to the rear of the frame. The front axle is attached to the center of the main frame by a pin and bushing arrangement at the middle of the axle. Thus the axle has a pivot point (6-219) that allows up and down oscillating movement of the wheels similar to that provided by the bolster assembly on articulated machines.

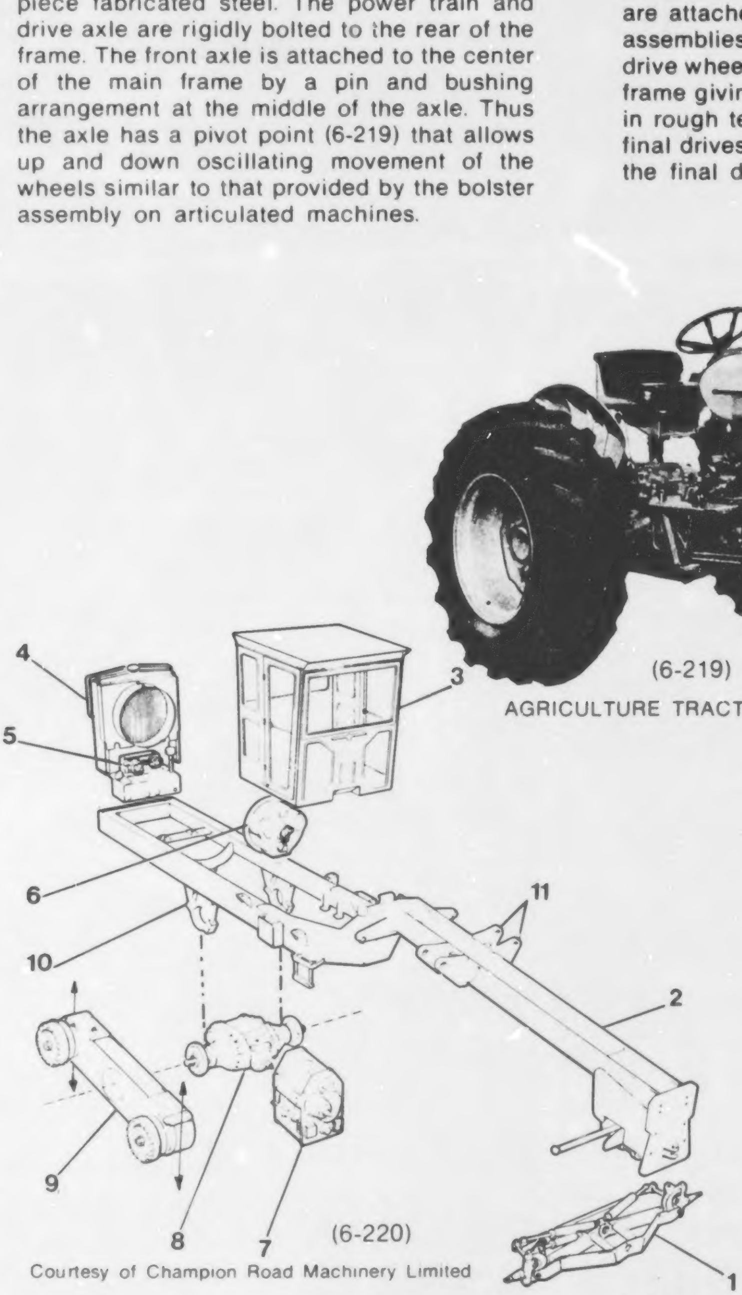
Motor Grader

Motor graders are yet another machine that uses rigid suspension. The frame (2, Figure 6-220) is the back bone of the grader. It consists of two cross-braced members that join near the middle of the frame to form a single arched beam that runs to the front axle (1). The two cross-braced members support the engine and power train components. The tandem wheel assemblies (9) (one on each side of the rear frame section for four wheel drive) are attached to the final drive (8) so that the assemblies pivot at the center point. Thus the drive wheels can oscillate parallel to the main frame giving the wheels good ground contact in rough terrain. The tandem assemblies and final drives are attached to the main frame by the final drive saddles (10).


FRONT AXLE PIVOTS AT THE CENTER

(6-219)
AGRICULTURE TRACTOR

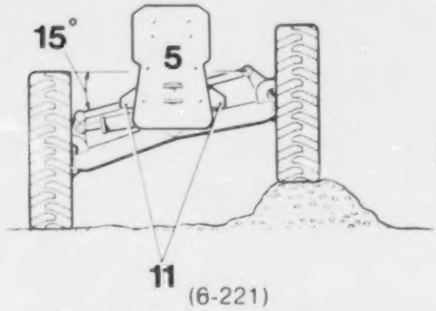
Courtesy of J.I.Case



(6-220)

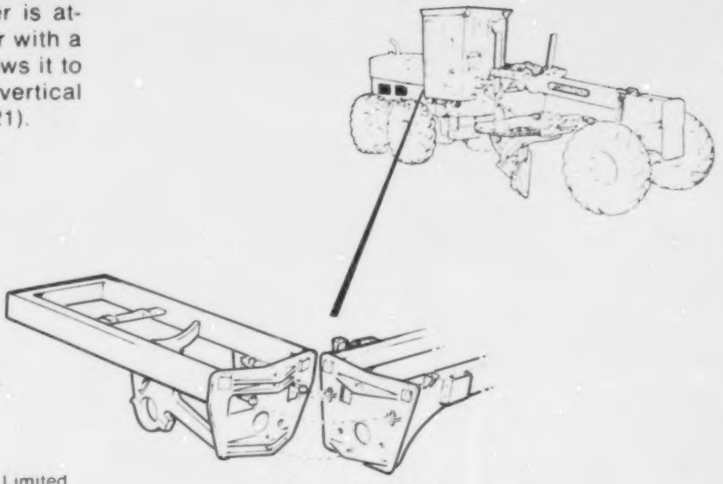
Courtesy of Champion Road Machinery Limited

The front axle assembly of the grader is attached to the main frame at the center with a pin and bushing arrangement that allows it to oscillate. Stops limit the amount of vertical movement of the wheels (Figure 6-221).



(6-221)

Courtesy of Champion Road Machinery Limited

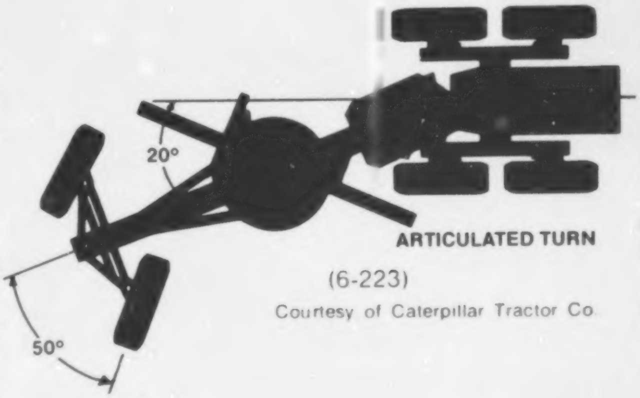


(6-222)

Courtesy of Champion Road Machinery Limited

The grader front axle is the steering axle. Besides turning, grader wheels can also tilt, a feature that improves handling on rough ground and gives sharper turns. Note in Figure 6-221 that, although the axle is oscillated the wheels are perpendicular; they have been tilted to offset the angle of oscillation. Grader steering is discussed in greater detail further on in this section.

A number of manufacturers now offer, as an option, an articulated grader frame (Figure 6-222). The frame is basically the same as the one described above but with a pivot point part way down the rear section. The articulated frame is used in combination with front axle steering to improve the machine's manoeuverability (Figure 6-223). Suspension mounting is the same as on the single frame models.



ARTICULATED TURN

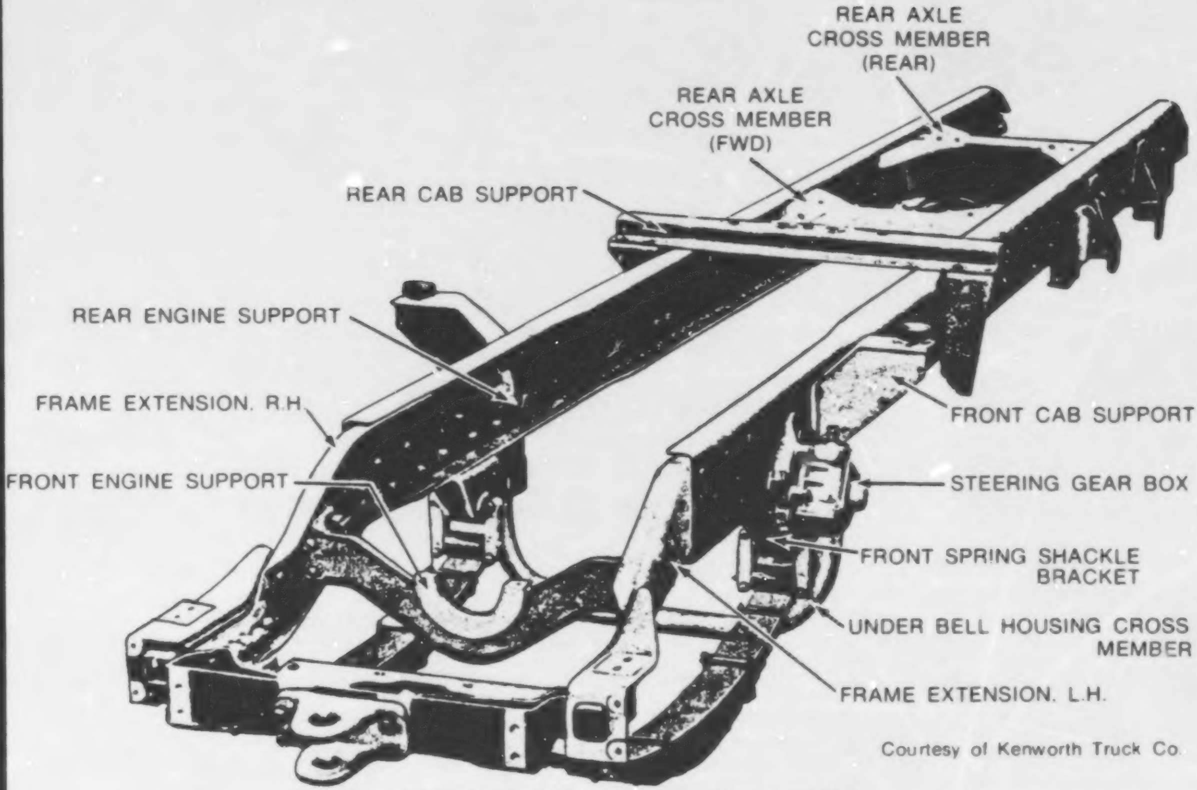
(6-223)

Courtesy of Caterpillar Tractor Co.

SPRING SUSPENSION

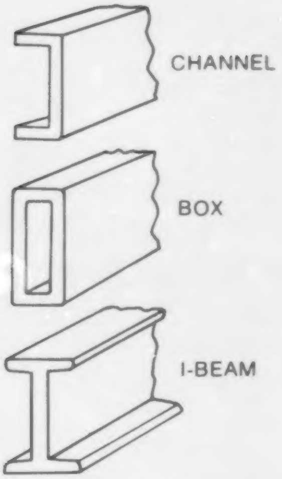
Frame

A spring suspension frame, like a rigid suspension frame, is the backbone of the vehicle. All other suspension parts are attached to it. Truck frames are constructed of basically two parts: side rails and cross members. The rails carry the load and the cross members stabilize the rails. The entire frame must be stiff enough to support the load it carries, yet it must be flexible enough to absorb and distribute the stress placed on it. Figure 6-224 shows a typical on-highway truck frame.


REAR AXLE CROSS MEMBER (REAR)
REAR AXLE CROSS MEMBER (FWD)
REAR CAB SUPPORT
REAR ENGINE SUPPORT
FRAME EXTENSION, R.H.
FRONT ENGINE SUPPORT
FRONT CAB SUPPORT
STEERING GEAR BOX
FRONT SPRING SHACKLE BRACKET
UNDER BELL HOUSING CROSS MEMBER
FRAME EXTENSION, L.H.

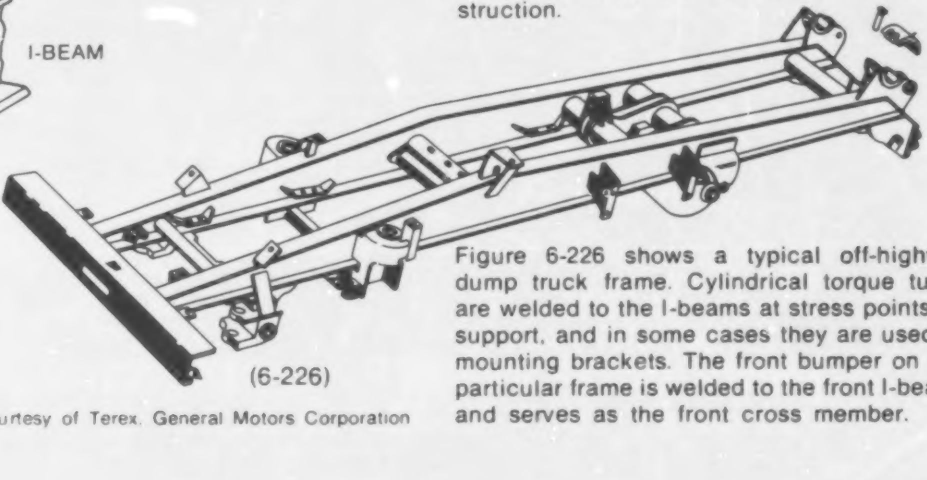
Courtesy of Kenworth Truck Co.

(6-224) **TYPICAL CONVENTIONAL FRAME**


CHANNEL
BOX
I-BEAM

(6-225)

Frames can be channel, box or I-beam shaped (Figure 6-225). Box construction is seldom used for truck frames, although some large off-highway trucks may use a fabricated box design. Highway trucks use channel frame construction, single or double rail (two channels together, one inside the other); the single can be steel or an aluminum alloy, the double is always steel. Aluminum is common when light weight is desired. Large off-highway trucks generally use the I-beam frame construction.



(6-226)

Courtesy of Terex, General Motors Corporation

Figure 6-226 shows a typical off-highway dump truck frame. Cylindrical torque tubes are welded to the I-beams at stress points for support, and in some cases they are used as mounting brackets. The front bumper on this particular frame is welded to the front I-beams and serves as the front cross member.

TYPES OF SPRING SUSPENSION

Because axles are bolted to the frames, rigid suspension systems have very little resilience. On The other hand, spring suspension systems have good resilience because springs allow axles to move independently of the frame. Springs reduce the shocks on the frame and frame components, thereby providing a smoother ride.

Trucks use several types of spring suspension, depending on the size of the truck and the kind of work it will be doing. Common types of spring suspensions are:

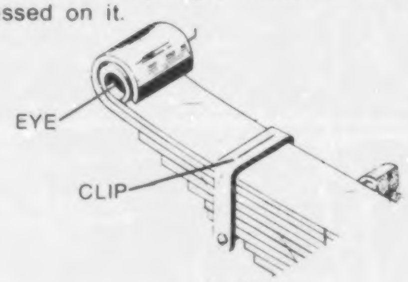
1. Springs — Leaf
   — Coil
   — Torsion Bar
2. Rubber
3. Hydro Air
4. Air

SPRINGS

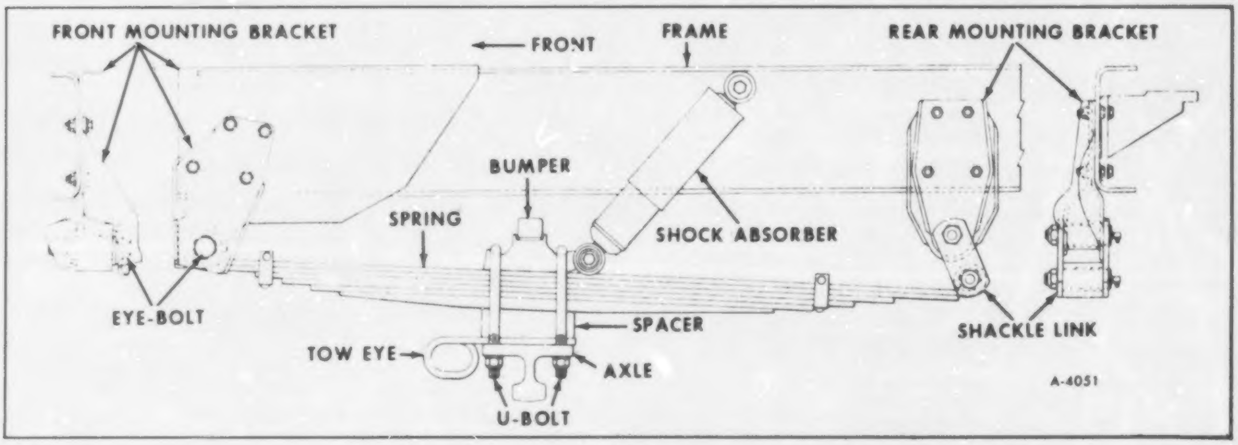
There are three basic types of springs: leaf, coil, and torsion bar. Coil and torsion bar springs are found mainly on automobiles and light duty vehicles. The discussion here is concerned with leaf springs which are used on light and heavy duty trucks.

Degree of hardness is an important characteristic of leaf springs. A spring must be stiff enough to carry the load yet be soft enough when the vehicle is unloaded to give a good ride. The stiffness of a spring is called its rate. The rate is the weight required to deflect a spring 2.54 cm (1 inch). If the rate of deflection is constant, it is called a constant-rate spring. For example, on a constant rate spring, if 227kg (500 lbs.) deflects the spring assembly 2.54 cm (1 inch), then 554 kg (1000 lbs.) would deflect the same spring assembly 5.08 cm (2 inches). Springs that do not deflect at a constant rate are called vari-rate or progressive rate springs.

A leaf spring assembly is made of a series of flat spring steel pieces called leaves. Starting with one or two long leaves called main leaves, the spring is built up with progressively shorter leaves. The number of leaves, their width, thickness and length will depend on where the spring will be used. The leaves are drilled at their centers and are held together by a special bolt called a center bolt. Clips are placed along the leaves on either side of the center bolt to keep the leaves aligned. If one main leaf is used, its ends are rolled to form an eye to hold a bushing and provide a means of attaching the spring to the frame. If two main leaves are used the second will often have an eye rolled around the first to give it extra support (Figure 6-227). New leaves are made with a slight curve or arc which allows the spring to flatten as the load is pressed on it.



(6-227)



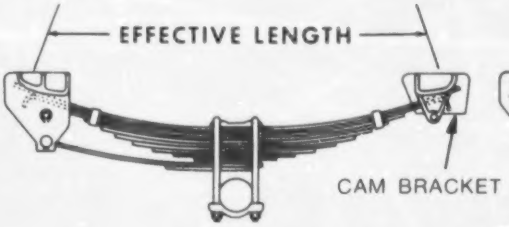
(6-228)

Courtesy of General Motors Corporation

Figure 6-228 shows the installation of a typical constant rate front spring. The spring is mounted to the axle with U-bolts, nuts and lock washers. The front end of the spring is mounted to a stationary bracket while the rear end of the spring is mounted to a spring shackle. The shackle allows for variations in spring length during compression and rebound of the spring. The center bolt, as well as holding the springs together, has another important function: the head of the center bolt fits into a hole in the axle or spacer to keep the axle square with the frame.

Progressive (Vari-rate) Springs

Progressive (vari-rate) springs are leaf spring assemblies with a variable deflection rate obtained by changing the effective length of the spring assembly (Figure 6-229). The length is varied by using a cam bracket at the rear of the spring. As the spring assembly deflects, the point of contact on the bracket moves toward the center of the spring assembly thereby shortening the effective length and making the spring stiffer. The spring movement inside the bracket is called slipper action. Vari-rate spring assemblies have another progressively stiffening feature in that the ends of a leaf don't contact the leaf above it when unloaded. As the spring assembly deflects, the ends of the leaves make contact giving increased stiffness.



UN-LOADED

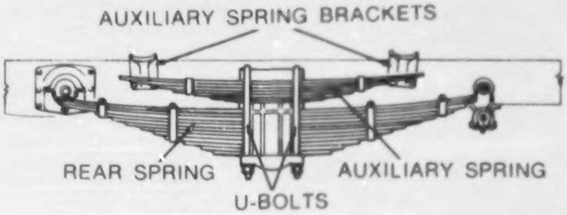
(6-229)

Courtesy of International Harvester

Both constant and progressive rate springs are used for front suspensions, but generally progressive rate springs are used for rear suspensions because they provide a softer spring when the vehicle is unloaded and a stiffer spring when the vehicle is loaded.

Auxiliary Springs

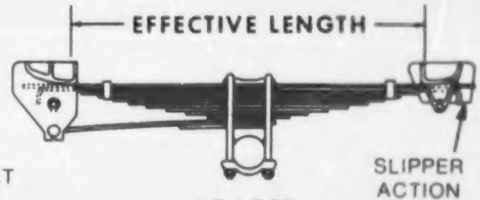
Auxiliary or overload springs are leaf spring assemblies usually mounted on top of the rear spring assemblies. Auxiliary springs come into action only when the vehicle is under heavy load. The auxiliary spring takes part of the load by contacting special brackets attached to the frame rail sides (Figure 6-230) when the load on the rear springs reaches an overload point.



(6-230) TYPICAL AUXILIARY SPRING

Tandem Axle Springs

To increase the carrying capacity and to provide more driving power, an extra axle and set of springs may be added to a truck. This addition is called a tandem axle and its suspension is referred to as tandem axle suspension. A tandem axle permits the truck to carry heavier loads because the load is distributed over a greater number of axles, springs and tires.



LOADED

(6-229)

Courtesy of International Harvester

A number of manufacturers specialize in building single and tandem axle suspension assemblies, and these assemblies are referred to by the manufacturer's name. For example, Hendrickson, Rockwell and Reyco are a few of the common suspension assemblies. Truck manufacturers often give a buyer an option as to what type (or manufacturer) of suspension he wants. Thus, even though two trucks have different names, e.g., Kenworth, White, G.M.C., Ford, etc., they could have the same suspension. On the other hand, some truck manufacturers such as Mack build their own suspension assemblies and these assemblies are referred to by the name of the truck manufacturer.

Rear Suspension

Front suspension on trucks is almost always leaf spring and is quite similar from truck to truck. However, differences do occur in rear suspension.

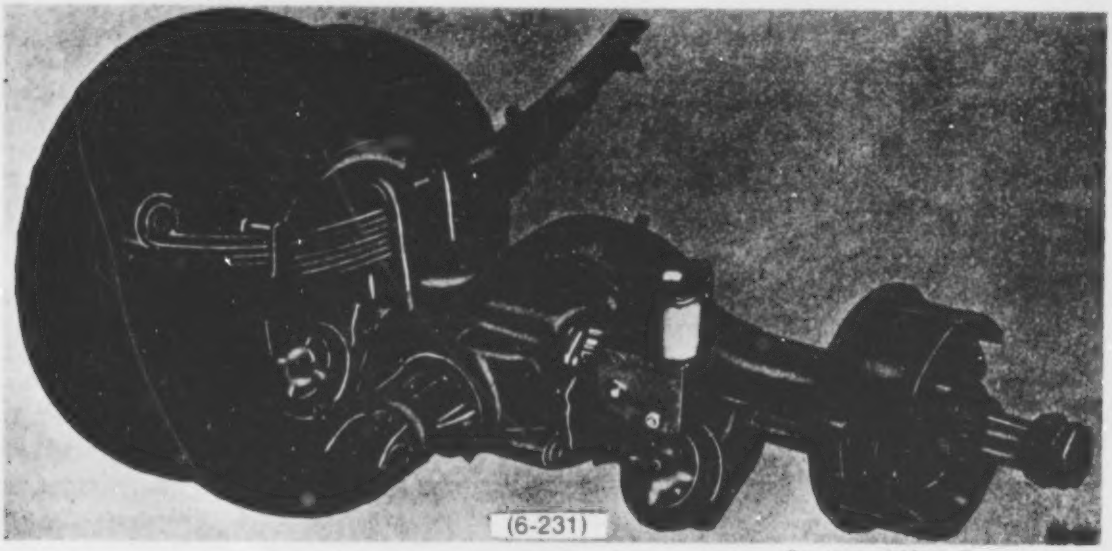
Single Axle Rear Suspension

Figure 6-231 shows a typical single-axle, leaf spring rear suspension. The spring has a single eye and a slipper on the rear. A pin attaches the eye to a bracket on the frame, and maintains axle alignment.

Another type of single-axle, leaf spring assembly (Figure 6-232) uses a torque rod rather than an eye and pin to attach the spring to the frame brackets. This particular assembly also has an auxiliary spring.

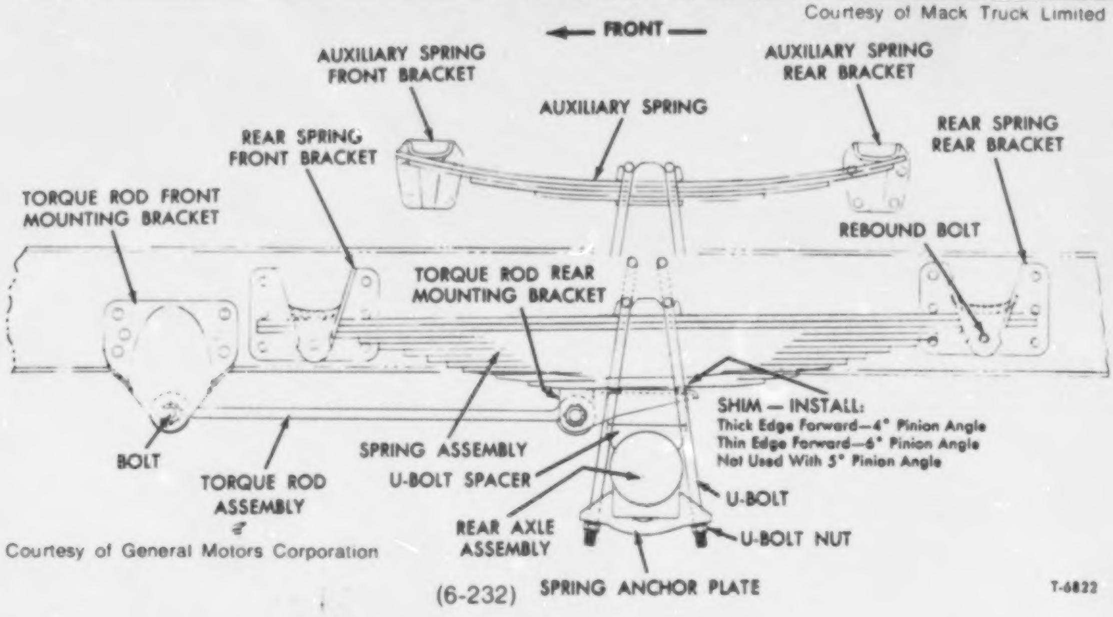
TANDEM DRIVE SUSPENSION

Tandem drive axles require a special suspension which will hold the axle housings in line with one another and with the frame and will allow independent oscillation of each wheel or axle housing. Tandem axle suspension must withstand rugged usage and give long service life. Several types of tandem suspensions are discussed below.



(6-231)

Courtesy of Mack Truck Limited


FRONT
AUXILIARY SPRING FRONT BRACKET
AUXILIARY SPRING REAR BRACKET
AUXILIARY SPRING
REAR SPRING FRONT BRACKET
REAR SPRING REAR BRACKET
TORQUE ROD FRONT MOUNTING BRACKET
REBOUND BOLT
TORQUE ROD REAR MOUNTING BRACKET
SHIM — INSTALL:
Thick Edge Forward—4° Pinion Angle
Thin Edge Forward—6° Pinion Angle
Not Used With 5° Pinion Angle
BOLT
TORQUE ROD ASSEMBLY
SPRING ASSEMBLY
U-BOLT SPACER
U-BOLT
REAR AXLE ASSEMBLY
U-BOLT NUT
SPRING ANCHOR PLATE
T-6822

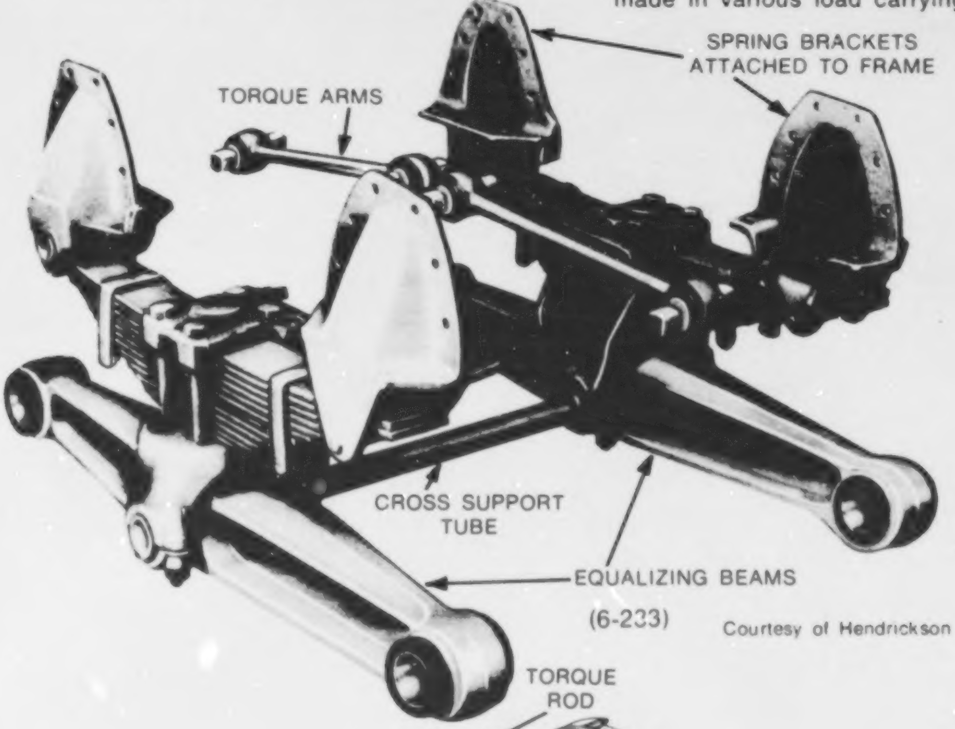
Courtesy of General Motors Corporation

(6-232)

Equalizer Beam — Leaf Spring Suspension (Hendrickson)

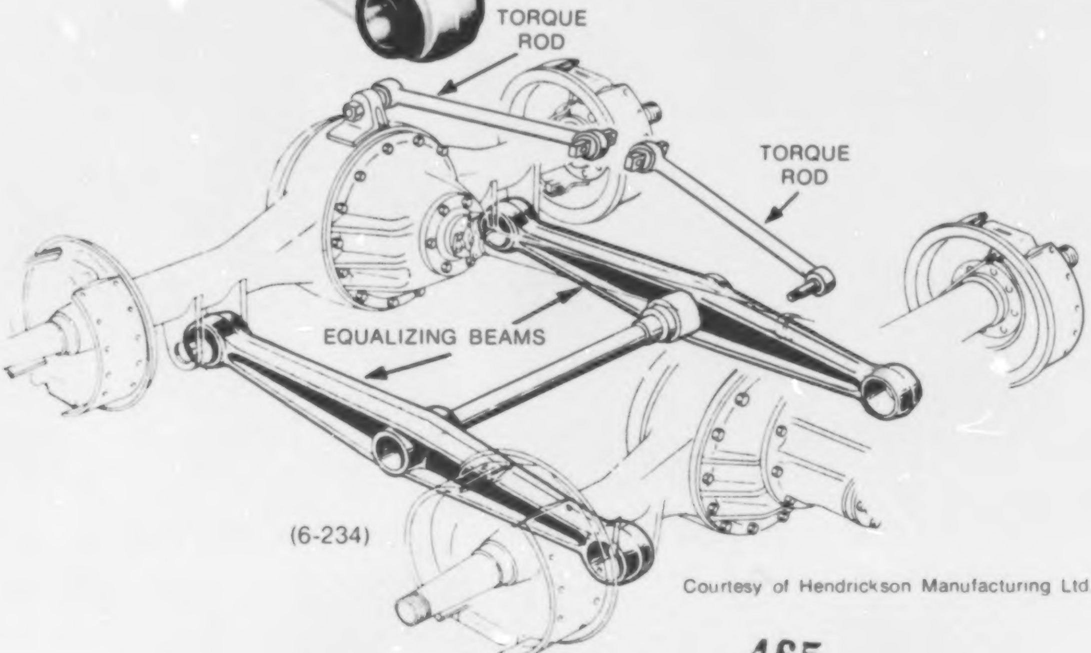
Equalizing beam suspension is available with leaf springs, rubber springs or air bags for tandem drive assemblies.

The most common type of equalizing beam suspension is a leaf spring assembly made by Hendrickson illustrated in Figures 6-233 and 6-234. This type of suspension is mainly used on highway trucks, although it is also found on some off-highway logging trucks. The springs are mounted on saddle assemblies above the equalizer beams and are pivoted at the front end on spring pins and brackets. The rear ends of the springs have no rigid attachment to the spring brackets, but are free to move forward and backwards in a slipper action to compensate for spring deflection. Equalizer beam, leaf spring suspension is made in various load carrying capacities.


SPRING BRACKETS ATTACHED TO FRAME
TORQUE ARMS
CROSS SUPPORT TUBE
EQUALIZING BEAMS

(6-233)

Courtesy of Hendrickson Manufacturing Ltd.

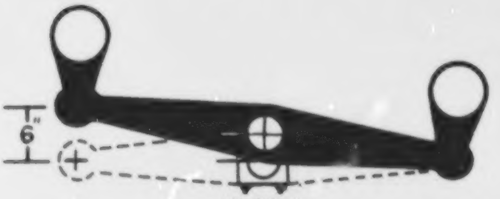

TORQUE ROD
TORQUE ROD
EQUALIZING BEAMS

(6-234)

Courtesy of Hendrickson Manufacturing Ltd.

Note the following points in installation of the equalizer beam, leaf spring suspension:

- The end of the cross support tube goes inside the saddle clamp.
- The equalizer beams are mounted below the axles, lowering the center of gravity and giving good stability.
- Torque arms are used for suspension alignment and stability.
- All mountings have rubber bushings and therefore only the spring eye pin at the front of each spring requires lubrication.
- Equalizing beam suspension uses the lever principles to reduce bumps by 50 percent. For example, if the wheel rises six inches going over a bump the load will only raise three inches (Figure 6-235).



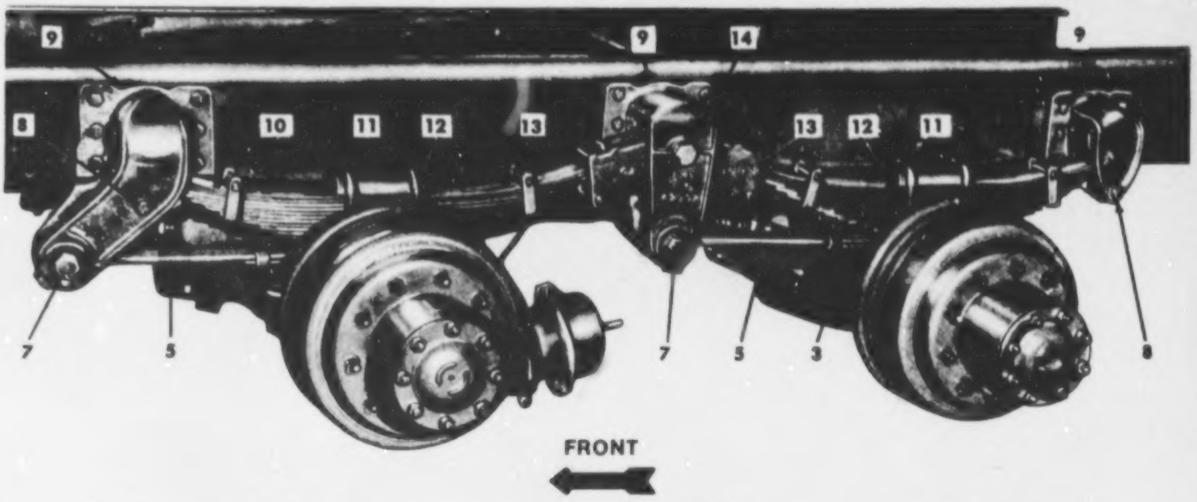
(6-235)

Courtesy of Hendrickson Manufacturing Ltd

Four-Spring Tandem Suspension (Reyco)

The Reyco suspension in Figure 6-236 is a four-spring tandem suspension mainly used for on-highway work. As in any conventional tandem suspension, the leaf spring assemblies carry the axles. The springs are mounted at three different locations on each side of the chassis and thus distribute the load over a large area of the frame rail.

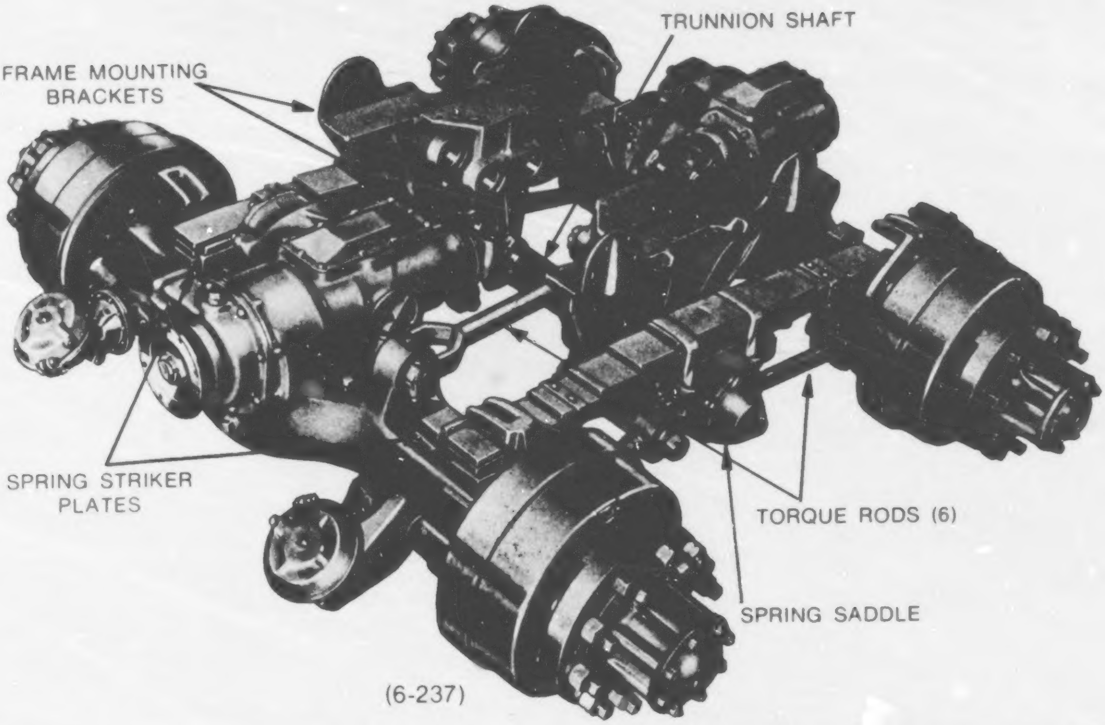
Reyco suspension differs from other types of four-spring suspension such as Dayton in that it uses torque leaves (5, in Figure 6-236) rather than torque rods to maintain suspension alignment and stability. Torque leaves provide stability by minimizing axle wind-up caused by driveline torque, and by load transfer during braking. Reyco suspension is aligned by adjusting eccentric bushings (6) located at the torque leaf mounting eyes.



1 U-Bolt Nut and Washer
2 Bottom Plate
3 Axle Housing
4 Spring Seat
5 Radius Leaf
6 Eccentric Adjustment
7 Radius Leaf Eye Bolt
8 Rebound Bolt
9 Spring Hanger
10 Spring
11 Spring U-Bolts
12 U-Bolt Spacer
13 Equalizer Arm
14 Equalizer Pivot Bolt

(6-236)

Courtesy of General Motors Corporation

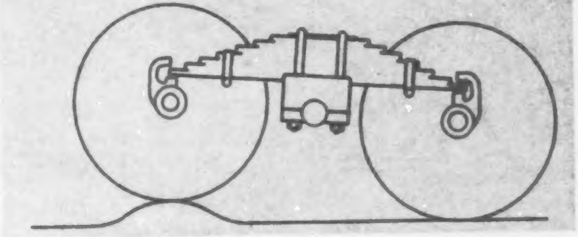


(6-237)

Courtesy of Rockwell International Automotive Operations

Rockwell Leaf Spring Tandem Suspension

On the Rockwell suspension in Figure 6-237, the load is equalized between the axles by two full-floating leaf springs. The springs rest at their outer ends on wear pads on the tops of the axle housings and are mounted on spring saddles by U-bolts at their centers. The springs and saddles are attached to, but free to oscillate on, a center member called a trunnion shaft. The trunnion shaft is essentially a dead axle attached to the frame mounting brackets. When a load is applied to the vehicle, force is applied in sequence to the frame brackets, the trunnion shaft, the spring saddles, the springs, and finally to the axle housings and wheels.



(6-238)

Courtesy of Rockwell International Automotive Operations

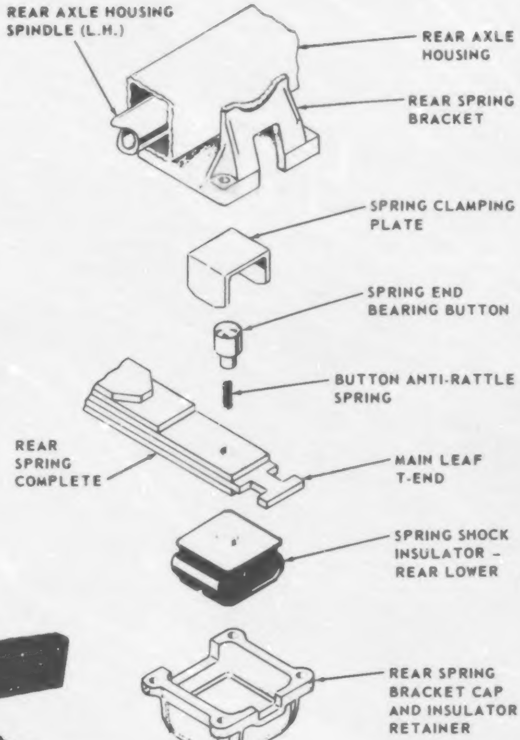
Oscillation of the springs and saddles on the trunnion (Figure 6-238) permit independent movement of the wheels and housings similar to the equalizing beam suspension. Transverse (sideways) movement of the axles is prevented by the spring striker plates welded on the axle housings.

Driving and braking forces are transmitted from the suspension to the chassis by a parallel torque rod system which also maintains the correct vertical position of the driving axles and prevents weight transfer between the axles. On the model shown in Figure 6-237 there are four torque rods on the bottom, two each side. These rods hold the housings in line with each other and square with the frame. Two more torque rods on the top maintain drive flange alignment.

The only lubrication needed in this Rockwell suspension is at the spring saddles and trunnion. A grease fitting or oil plug is supplied. Rockwell suspension systems are available in various load carrying capacities and are found on many on-highway and off-highway tandem drive trucks.

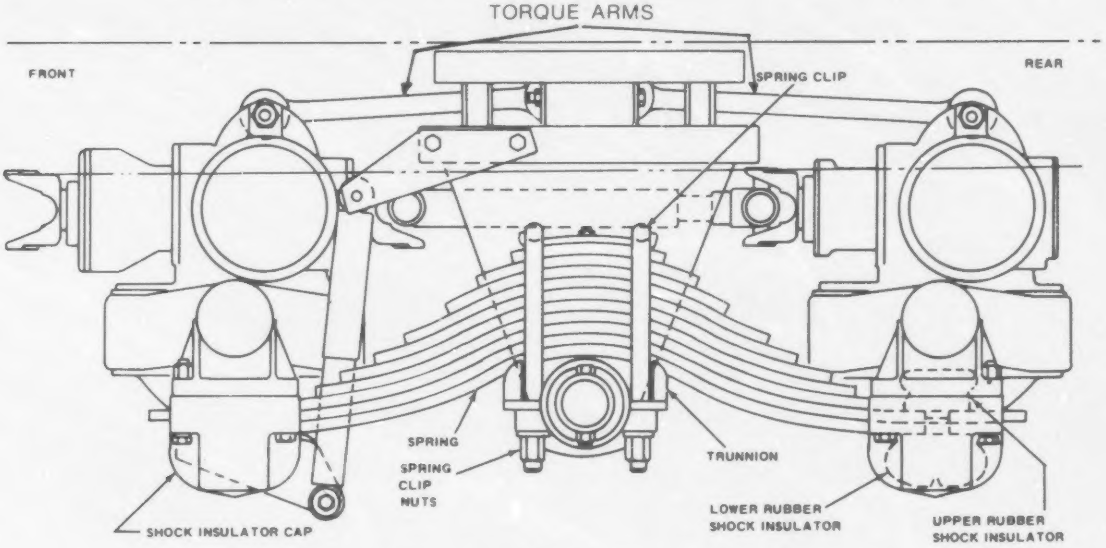
Mack Leaf Suspension

Mack leaf suspension is similar to Rockwell suspension except that the spring is underslung which lowers the vehicle's center of gravity (Figure 6-239) The springs are mounted on saddles which in turn are attached to a trunnion. Spring ends are secured to the axle housings through rubber shock insulators (Figure 6-240) slung below the axles. These insulators serve to hold the housings in line and eliminate the need for lower torque arms. Oscillation of the spring and saddle assembly permits independent wheel and housing movement. Axle housings are braced against rotation from driving and braking by upper torque arms, seen in the typical Mack camelback spring assembly in Figure 6-241. Mack leaf suspension is lubricated at the point where the spring saddle oscillates on the trunnion (Figure 6-242).

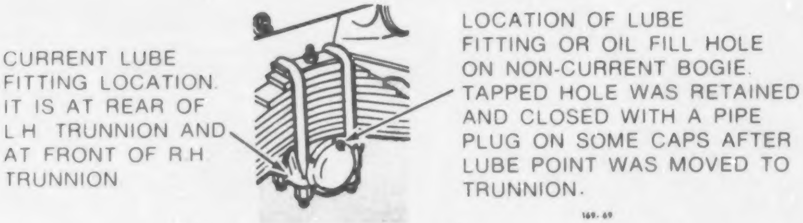

REAR AXLE HOUSING SPINDLE (L.H.)
REAR AXLE HOUSING
REAR SPRING BRACKET
SPRING CLAMPING PLATE
SPRING END BEARING BUTTON
BUTTON ANTI-RATTLE SPRING
REAR SPRING COMPLETE
MAIN LEAF T-END
SPRING SHOCK INSULATOR – REAR LOWER
REAR SPRING BRACKET CAP AND INSULATOR RETAINER
188-1

(6-240) SPRING END CONFIGURATION
Courtesy of Mack Truck Ltd.

(6-239)
Courtesy of Mack Truck Ltd.


TORQUE ARMS
FRONT
REAR
SPRING CLIP
SPRING
SPRING CLIP NUTS
TRUNNION
SHOCK INSULATOR CAP
LOWER RUBBER SHOCK INSULATOR
UPPER RUBBER SHOCK INSULATOR
169-54

(6-241) TYPICAL CAMELBACK SPRING ASSEMBLY
Courtesy of Mack Truck Ltd


CURRENT LUBE FITTING LOCATION. IT IS AT REAR OF L.H. TRUNNION AND AT FRONT OF R.H. TRUNNION
LOCATION OF LUBE FITTING OR OIL FILL HOLE ON NON-CURRENT BOGIE. TAPPED HOLE WAS RETAINED AND CLOSED WITH A PIPE PLUG ON SOME CAPS AFTER LUBE POINT WAS MOVED TO TRUNNION.
169-69

(6-242) LUBE FITTING LOCATION SPRING TYPE BOGIE

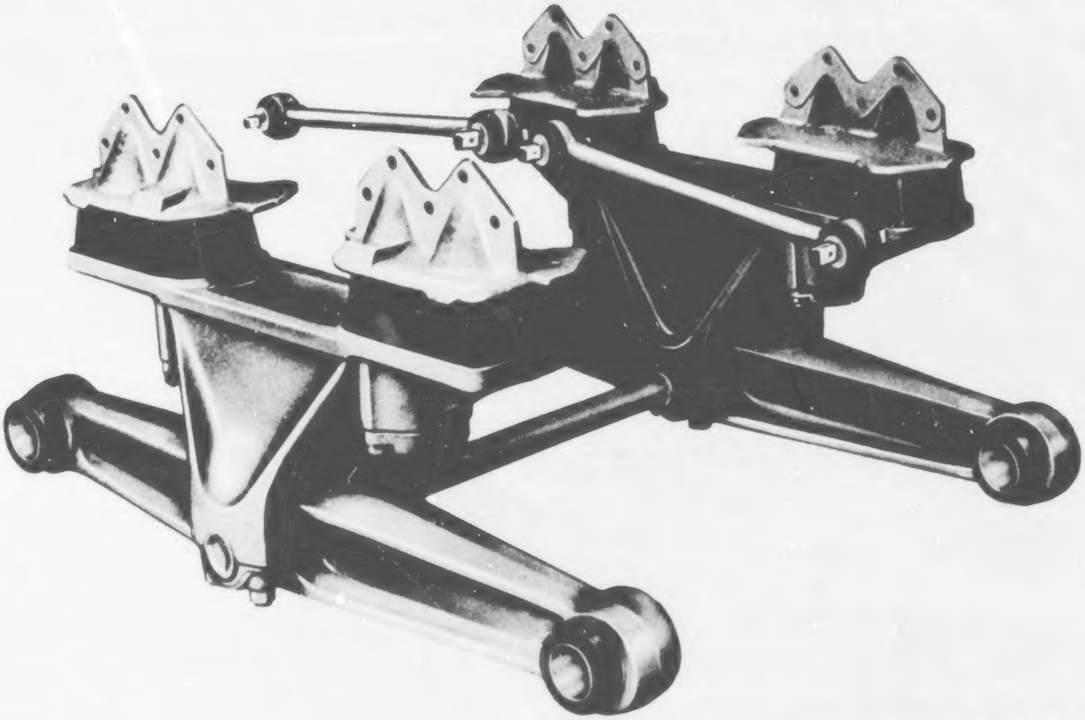
Courtesy of Mack Truck Ltd.

Mack leaf suspension is available in capacities of 34,000 lbs. to 80,000 lbs. and is suitable for both on-highway and off-highway service.

RUBBER SUSPENSION

Rubber Spring Suspension

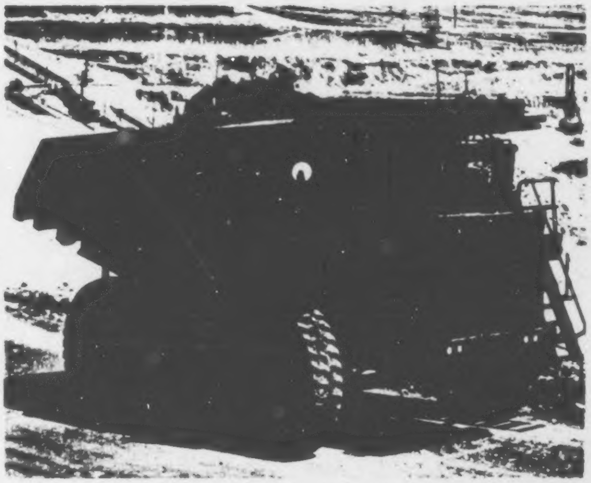
Another popular type of tandem suspension (also available for single axle suspension) is rubber spring suspension. It is very rugged and it comes in a variety of load ratings making it adaptable to both on-highway and off-highway vehicles. The rubber suspension in Figure 6-243 is made by Hendrickson and is almost identical to the Hendrickson leaf spring suspension except that rubber blocks replace the springs.



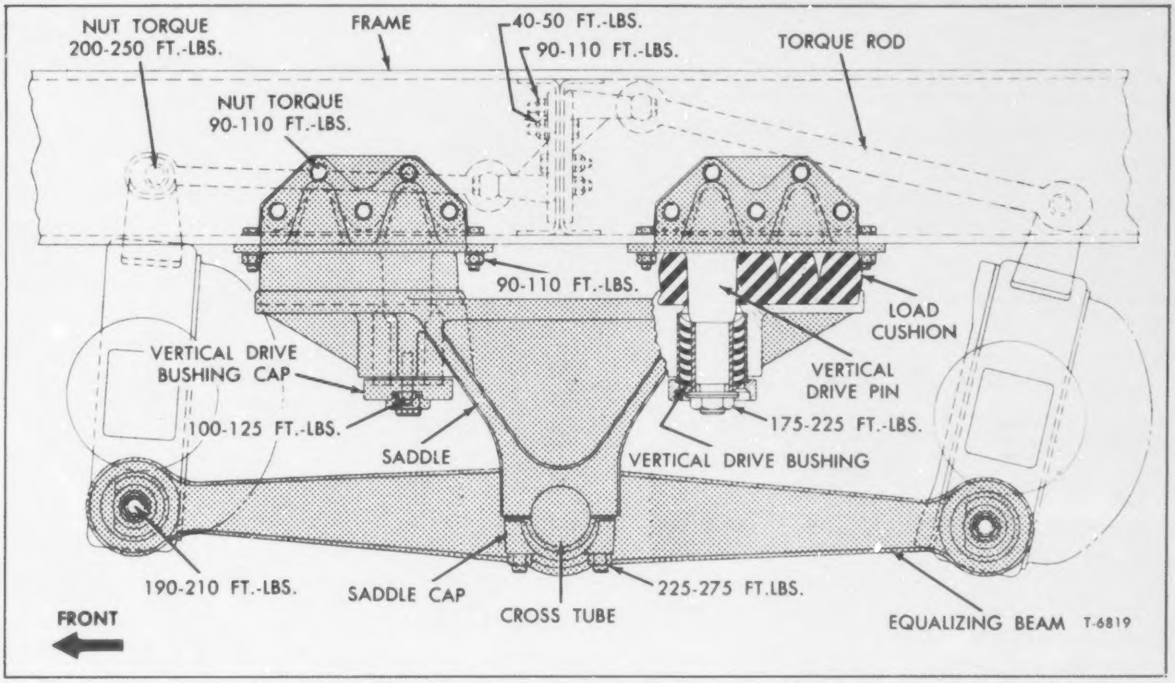
(6-243) Courtesy of Hendrickson Manufacturing Ltd.

The rubber cushions are mounted on saddles. The frame brackets are secured to the rubber suspension cushions by rubber-bushed drive pins (Figure 6-244). Without load, the unit rides on the outer edge of the cushions. As the load increases, the crossbars of the cushions are progressively brought into contact to absorb the additional load. The four drive pins maintain suspension alignment, the rubber bushings permitting the drive pins to move up and down in direct relation to movement of the load cushions.

The equalizing beams carry the load and act as the lower torque rods. As shown in Figure 6-244, upper torque rods are required, similar to previously described suspension assemblies.



(6-245) Courtesy of Unit Rig and Equipment Co.


NUT TORQUE 200-250 FT.-LBS.
FRAME
40-50 FT.-LBS.
90-110 FT.-LBS.
TORQUE ROD
NUT TORQUE 90-110 FT.-LBS.
90-110 FT.-LBS.
LOAD CUSHION
VERTICAL DRIVE BUSHING CAP
VERTICAL DRIVE PIN
100-125 FT.-LBS.
175-225 FT.-LBS.
SADDLE
VERTICAL DRIVE BUSHING
190-210 FT.-LBS.
SADDLE CAP
225-275 FT.LBS.
CROSS TUBE
FRONT
EQUALIZING BEAM
T-6819

(6-244) TANDEM REAR AXLE SUSPENSION
(HENDRICKSON RS-380)

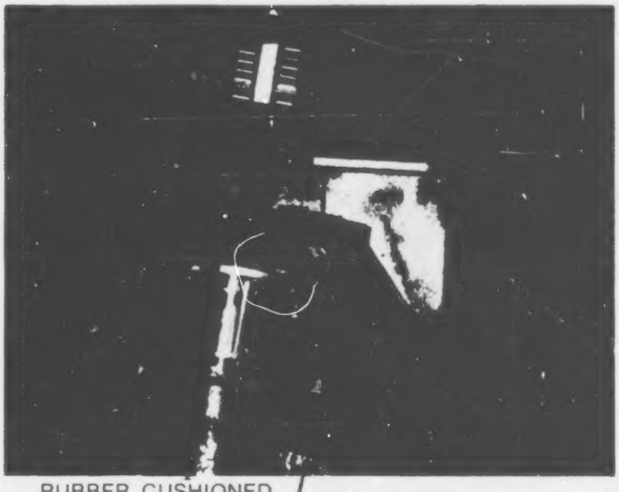
Courtesy of General Motors Corporation

Rubber Column Suspension

Another type of rubber suspension is used on large off-highway mine haulage trucks such as seen in Figure 6-245.

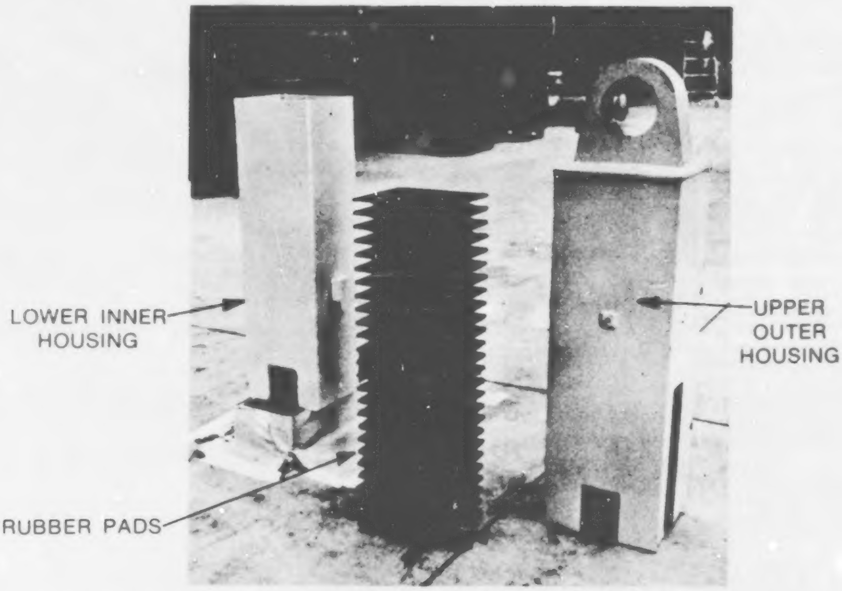
This truck has a rubber cushioned suspension unit at each wheel. The units are columnar shaped at the front, and rectangular at the back. The rear axle box is suspended by two units, one at each rear corner, while the front suspension is two independent units. Each suspension unit consists of a column of rubber pads inside two concentric suspension housings. Compression of the rubber pads provides the cushioning effect.

A front suspension unit is shown in Figure 6-246. Note that this cylinder, as well as supporting the vehicle, also has a steering arm that attaches to the front wheel.


RUBBER CUSHIONED SUSPENSION UNIT
STEERING ARM

(6-246)
Courtesy of Unit Rig Equipment Co.

Figure 6-247 shows a rear suspension unit. The lower, inner housing slides within the upper, outer housing and the rubber pads provide the cushioning between the two. The upper housing and the rubber pads provide the cushioning between the two. The upper housing is attached to the frame through a spherical bushing, while the lower housing is attached to the axle box by a clevis and pin arrangement. Mountings for these rubber suspension units are discussed along with hydro-air suspension mountings.


LOWER INNER HOUSING
UPPER OUTER HOUSING
RUBBER PADS

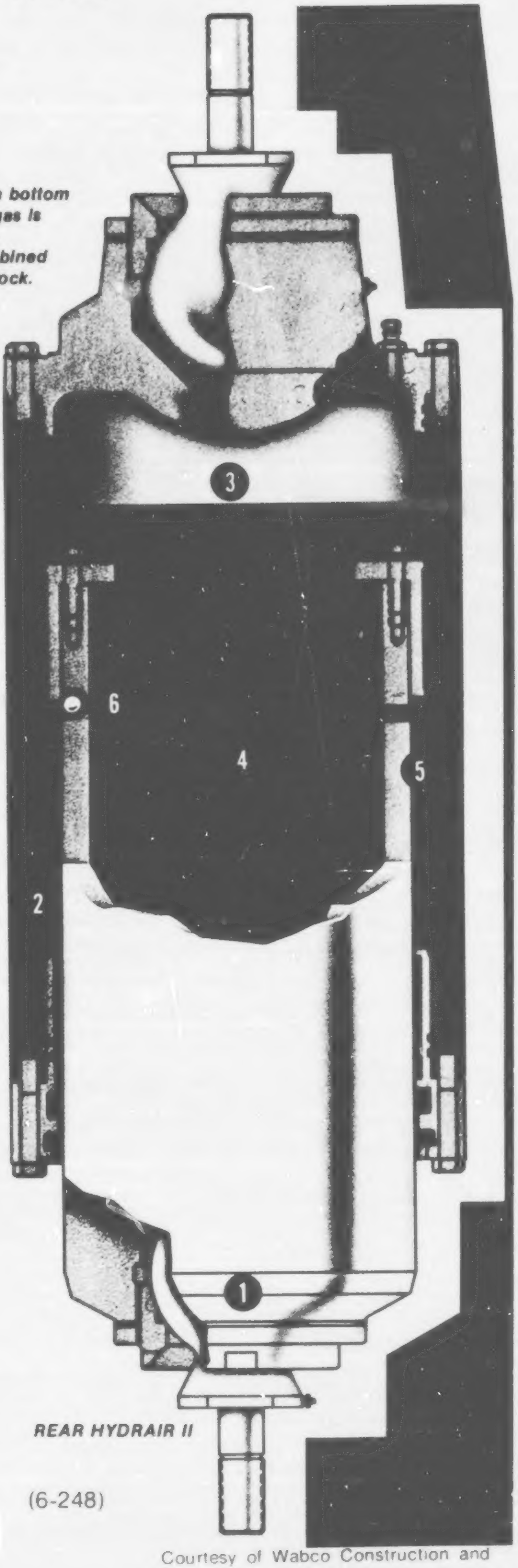
(6-247) REAR SUSPENSION
Courtesy of Unit Rig Equipment Co.

HYDRO-AIR SUSPENSION

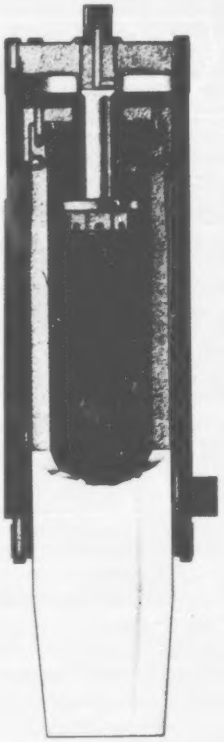
Hydro-air suspension is generally found on large off-highway haulage trucks. Caterpillar, Wabco, Terex, are but a few of the manufacturers who use hydro-air suspension (Figure 6-248).

HYDRAIR Suspension. When bottom section slides up, nitrogen gas is compressed, forcing oil into annular chamber — the combined cushioning absorbing the shock. Ball check valves prevent oil from flowing back too quickly.

1. **Bottom section**
2. **Suspension housing**
3. **Nitrogen Gas**
4. **Oil (Main Chamber)**
5. **Annular (damping) chamber**
6. **Ball check valve**



REAR HYDRAIR II



FRONT HYDRAIR II

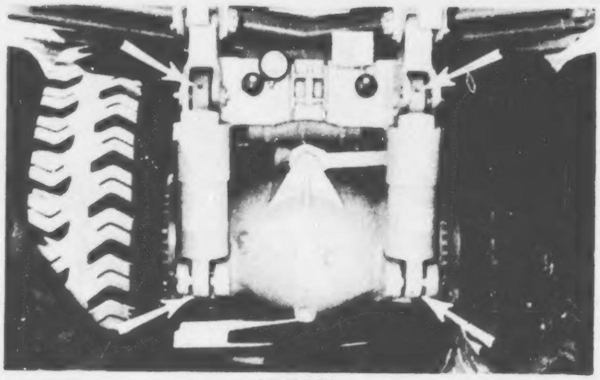
(6-248)

Courtesy of Wabco Construction and Mining Equipment

Figure 6-249 shows the suspension cylinders as viewed from the front and the rear of the vehicle. The two front cylinders act not only as a spring and shock absorber but also as a king pin for steering. The suspension cylinder piston has an up and down motion for spring and shock absorber action, and a rotary motion for steering action.

(6-249)

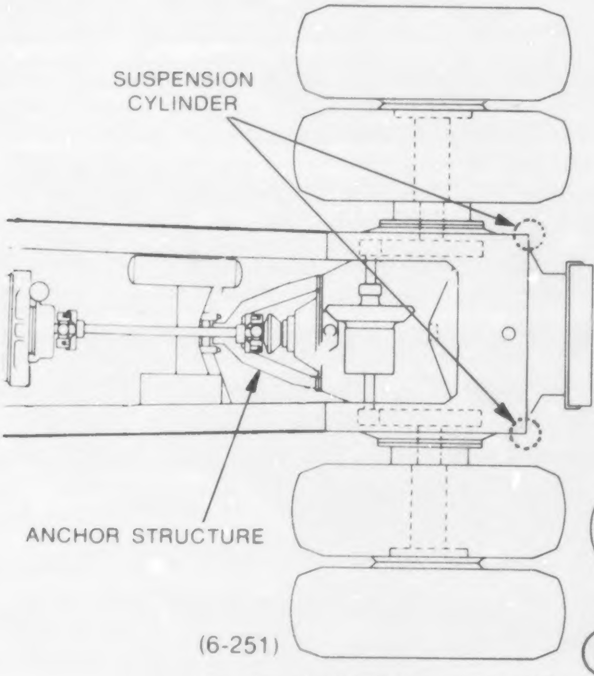
Courtesy of Caterpillar Tractor Co



(6-250)

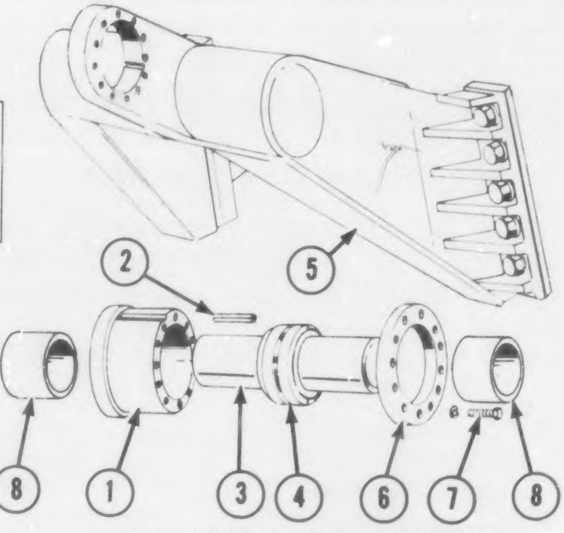
Courtesy of Caterpillar Tractor Co

The two rear suspension cylinders are attached at the bottom to the axle and at the top to the ends of the frame (Figure 6-250). The axle housing is supported at the front by a Y-shaped member called an anchor structure. The anchor (Figures 6-251 and 6-252) is attached to the front of the housing in two places and to the frame at one point. This Wabco frame attachment has a ball bushing arrangement which allows the housing to oscillate from side to side, as well as vertically, yet still hold the housing in line. Caterpillar uses a similar anchor structure on their rear hydro-air suspension. One difference, though, is that Cat uses an anchor ball rather than a ball bushing at the frame attachment.



(6-251)

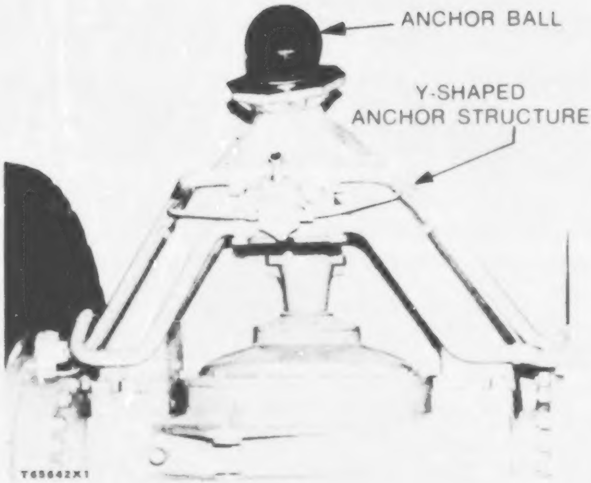
Courtesy of Wabco Construction and Mining Equipment



(6-252) ANCHOR PIN ASSEMBLY

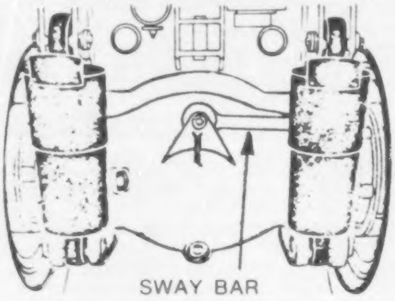
1. Ball Bushing Cage
2. Spring Pin
3. Anchor Pin
4. Ball Bushing
5. Anchor Structure
6. Retainer Plate
7. Capscrew
8. Spacer

Courtesy of Wabco Construction and Mining Equipment



(6-253)
Courtesy of Caterpillar Tractor Co.

For additional rear axle stability, a sway bar (Figure 6-254) is attached to the top of the axle housing and is anchored to the frame rail. The sway bar absorbs lateral thrusts.



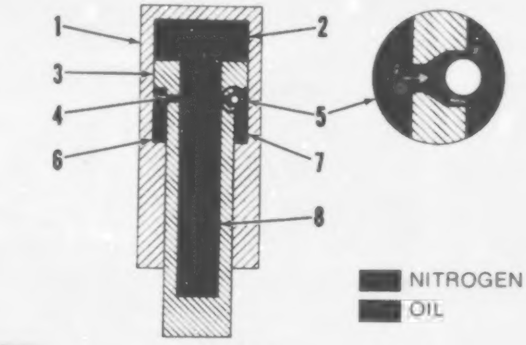
(6-254) VIEW FROM REAR OF MACHINE
Courtesy of Caterpillar Tractor Co.

Hydro-Air Cylinder Operation

Front Suspension

The front suspension cylinders consist of a cylinder and a piston or rod. The cylinder is attached to the truck frame and the piston or rod to the front wheel spindles. When the wheel hits a bump, the piston moves up into the cylinder. A chamber (2, in Figure 6-255) between the head of the piston and the top of the cylinder is charged with pressurized nitrogen gas and cushions the piston as it comes up into the cylinder. The piston (3) has a hollow core (8) that is filled with oil.

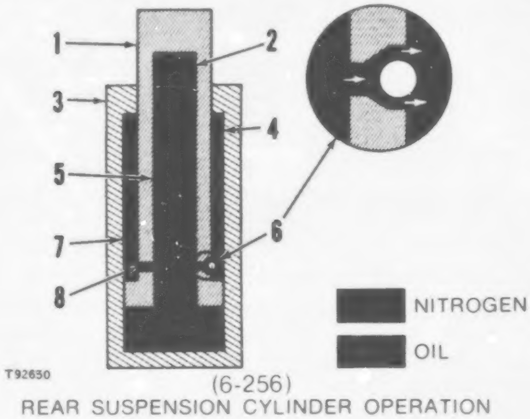
As the piston is pushed into the nitrogen, pressure on the oil transfers some of the oil from the core of the piston through orifices (4) to cavities (6) and (7). The transfer of oil into and out of the cavities gives a damping action that prevents the piston from bottoming in the cylinder with a shock when it comes back down.



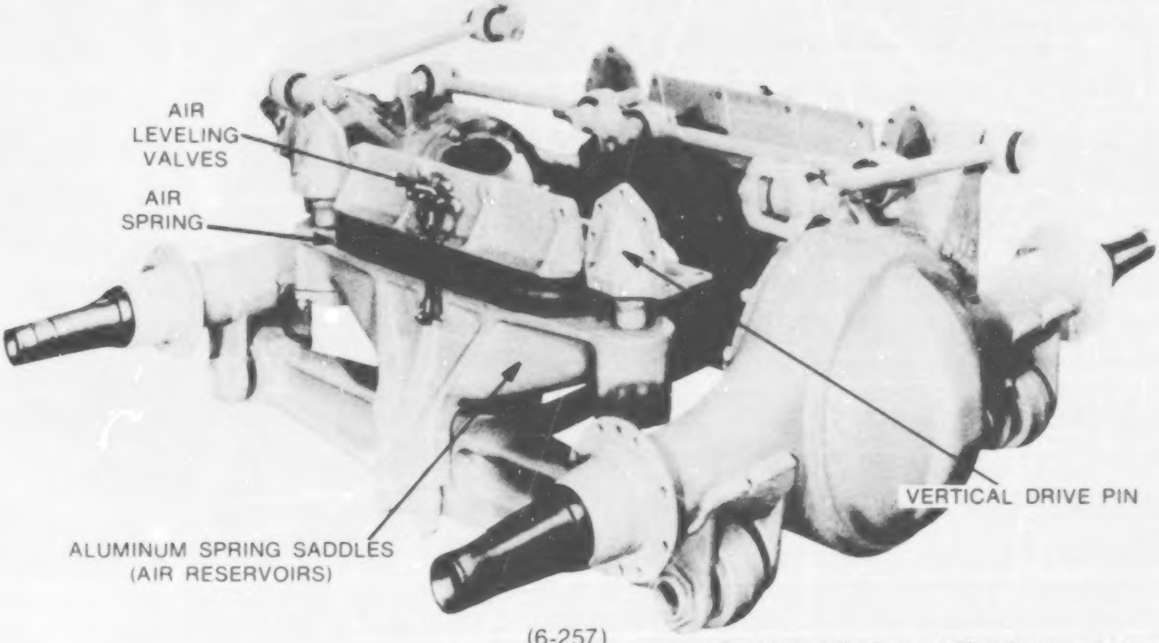
(6-255)
FRONT SUSPENSION CYLINDER OPERATION
1—Cylinder. 2—Nitrogen chamber. 3—Piston. 4—Orifices (two). 5—Ball check. 6—Cavity. 7—Cavity. 8—Oil chamber.
Courtesy of Caterpillar Tractor Co.

Rear Suspension

The cylinder and piston in rear suspension (Figure 6-256) work opposite to the cylinder and piston in front suspension. The piston is attached to the frame and the cylinder is attached to the rear axle. When the rear wheels hit a bump, the axle raises and the cylinder moves up over the piston. In rear suspension, the nitrogen chamber (2) is in the core of the piston and the cylinder is filled with oil. As the cylinder moves up, it is cushioned by the pressurized nitrogen pushing against the oil. As in front suspension, a damping action is created by oil transfer into and out of cavities (4) and (7).



(6-256)
REAR SUSPENSION CYLINDER OPERATION
1—Rod. 2—Nitrogen chamber. 3—Housing. 4—Cavity. 5—Oil chamber. 6—Ball check. 7—Cavity. 8—Orifice.
Courtesy of Caterpillar Tractor Co.


AIR
LEVELING
VALVES
AIR
SPRING
VERTICAL DRIVE PIN
ALUMINUM SPRING SADDLES
(AIR RESERVOIRS)

(6-257)

Courtesy of Hendrickson Manufacturing Ltd.

AIR SUSPENSION

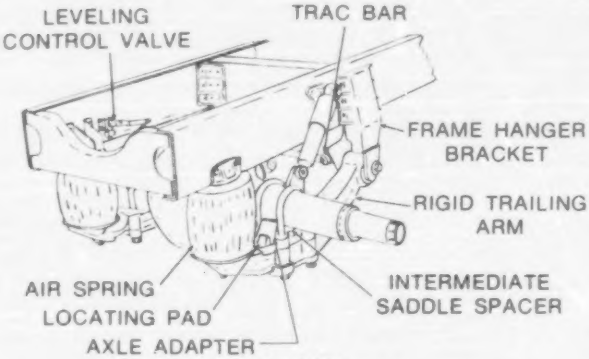
Another type of suspension is air suspension. It is mainly used for transport vehicles that require a soft ride such as furniture vans and buses. There are a number of air suspension systems manufactured. Three common ones are discussed here: Hendrickson, International, and G.M.C.

Hendrickson

The Hendrickson air spring in Figure 6-257 uses the same basic design as the Hendrickson leaf and rubber suspension previously discussed. Air suspension is accomplished through the use of air springs mounted on aluminum spring saddles which also serve as air reservoirs. Vertical drive pins are mounted in rubber bushings and relieve the air spring of any function except cushioning the load. Leveling valves are externally mounted. They automatically regulate the amount of air pressure required for the load, as well as keep the vehicle frame at a constant height.

International Harvester Air Suspension

Air suspension used on a single axle International truck is illustrated in Figure 6-258. The parts are described below:


LEVELING
CONTROL VALVE
TRAC BAR
FRAME HANGER
BRACKET
RIGID TRAILING
ARM
INTERMEDIATE
SADDLE SPACER
AIR SPRING
LOCATING PAD
AXLE ADAPTER

(6-258)

Courtesy of International Harvester

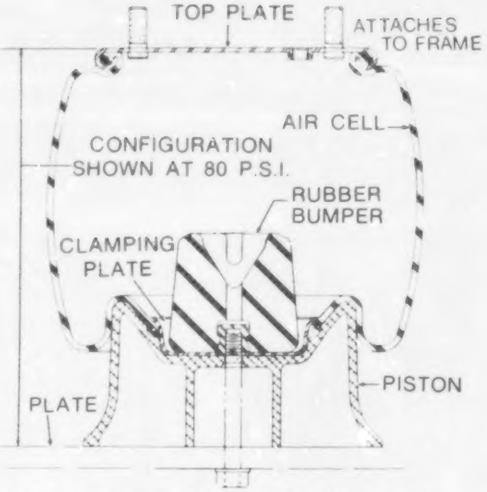
Trailing Arms — The front end of the trailing arm is connected to the frame hanger bracket. The rear of the arm has a support plate for the air spring.

Frame Hanger Brackets — The frame hanger brackets form the pivot point for each trailing arm. A rubber bushing and bolt are used to connect the trailing arm to the hanger bracket.

Shock Absorbers — The shock absorbers are mounted at the frame and axle saddles. They incorporate a hydraulic lock which reduces suspension shock by letting the suspension down easy when the axle is in its downward travel.

Trac Bar — The trac bar, prevents lateral sway of the vehicle suspension. There is one trac bar on chassis with single axles and two on chassis with tandem axles.

Air Springs — The rolling sleeve bag is mounted between the top plate and the piston (Figure 6-259). As the air spring (sleeve bag) is compressed, the air cell rolls over the piston. A rubber bumper is located internally to prevent metal-to-metal contact. The rubber bumper can either be located at the top or bottom of the air spring. The air bags work in unison from front to rear (not side to side). There is no transfer of air from bag to bag because this would cause axle roll.


TOP PLATE
ATTACHES TO FRAME
AIR CELL
CONFIGURATION SHOWN AT 80 P.S.I.
RUBBER BUMPER
CLAMPING PLATE
PISTON
PLATE

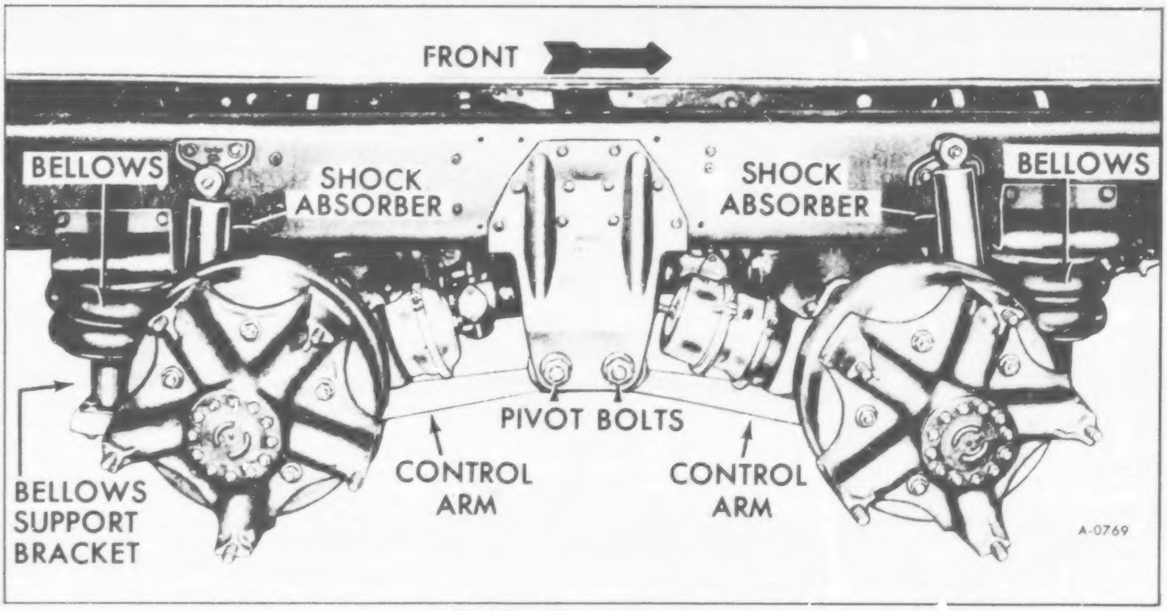
(6-259) AIR SPRING ASSEMBLY

Courtesy of International Harvester

Leveling Valves — The control (leveling) valve operates automatically. Valves control the flow of compressed air into or out of the air springs.

G.M.C. Air Suspension

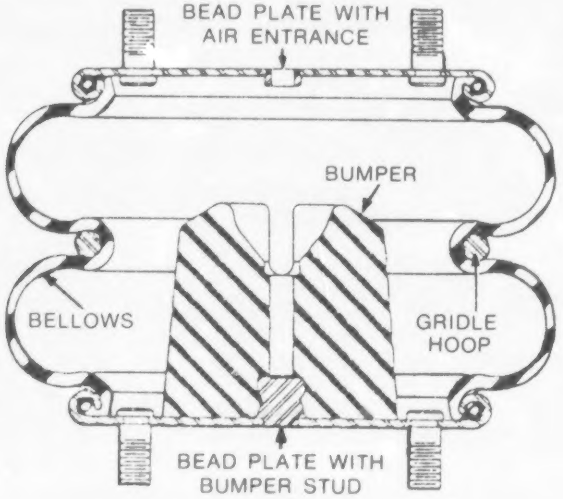
The G.M.C. air suspension in Figure 6-260 consists mainly of air springs (bellows) a height control valve, control arms, and shock absorbers.


FRONT
BELLOWS
SHOCK ABSORBER
SHOCK ABSORBER
BELLOWS
PIVOT BOLTS
CONTROL ARM
CONTROL ARM
BELLOWS SUPPORT BRACKET
A-0769

(6-260) AIR SUSPENSION SYSTEM

Courtesy of General Motors Corporation

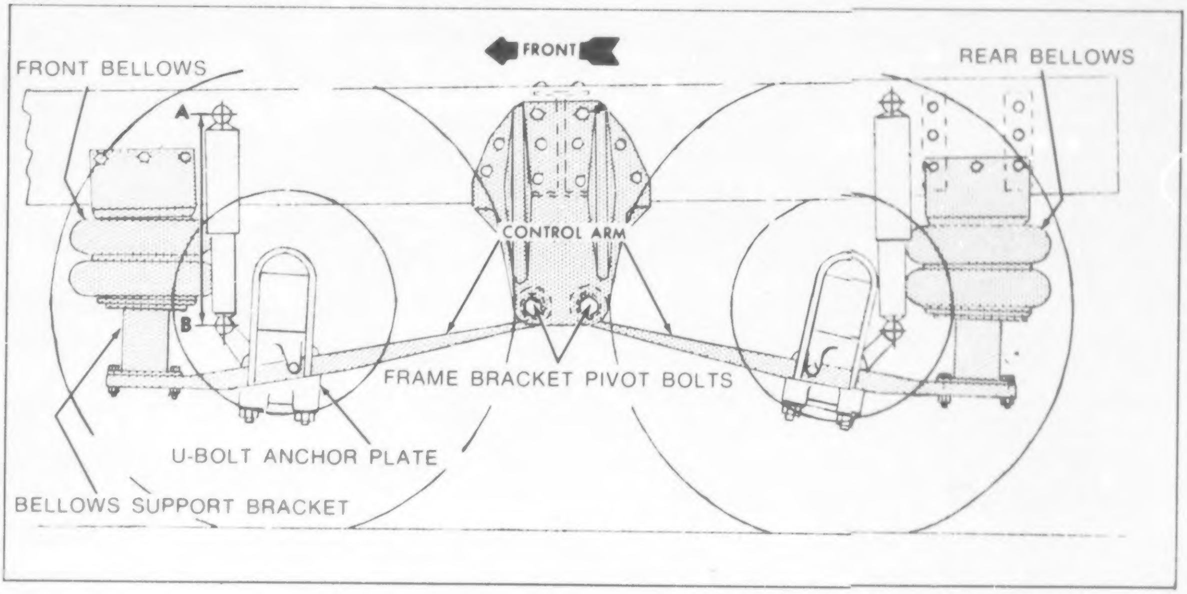
Air Bellows — An air bellows (Figure 6-261) is mounted between each control arm and frame support bracket. The bellows serves as a flexible connection between the frame and rear axles. Flexing of the air bellows results in an alternate increase and decrease of air volume. This action absorbs road shocks in a manner similar to an inflated rubber tire.


BEAD PLATE WITH AIR ENTRANCE
BUMPER
BELLOWS
GRIDLE HOOP
BEAD PLATE WITH BUMPER STUD

(6-261)

Height Control Valve — The height control valve is mounted to the frame and attached to the forward rear axle by a non-adjustable link. The valve operates when the vehicle's load increases or decreases, automatically increasing or decreasing pressure in the bellows. As the frame settles under an increased load, the height control arm linked to the forward rear axle is moved upward. The arm actuates the valve, and a sufficient volume of air is admitted to all four bellows to maintain the frame at normal ride height. During unloading, the valve exhausts air from the bellows.

Axle Control Arms — Control arms hold the rear axle in position, transmit driving and braking forces to the frame, and provide roll stability. A good view of control arms is given in Figure 6-262.


FRONT
FRONT BELLOWS
REAR BELLOWS
A
B
CONTROL ARM
FRAME BRACKET PIVOT BOLTS
U-BOLT ANCHOR PLATE
BELLOWS SUPPORT BRACKET

Courtesy of General Motors Corporation

(6-262)

QUESTIONS — WHEEL MACHINE SUSPENSION

1. What are the two main types of suspension for wheel machines? Briefly state the advantage of each, and give an example of a machine where each is used.

2. What is the function of a bolster in rigid suspension?

3. How does a skidder frame differ from a loader frame?

4. How does grader suspension give maximum wheel contact with the ground?

5. Truck frames are constructed of basically two parts: ____________ and ____________.

6. Frames may be constructed of three shapes of material:
   (a) I-beam, round tubing and flat.
   (b) channel, box and I-beam.
   (c) channel, flat and round.
   (d) I-beam, channel and flat.

7. List the four common types of spring suspension.

8. The stiffness of a leaf spring is referred to as its:
   (a) hardness
   (b) resilience
   (c) rate
   (d) size

9. Briefly explain the difference between a constant rate spring and a progressive rate spring.

10. What is the advantage of a progressive rate over a constant rate spring?

11. A tandem axle suspension permits the truck to carry heavier loads because the load is distributed over:
    (a) the cab of the truck.
    (b) one axle when unloaded and two when loaded.
    (c) a greater number of springs.
    (d) a greater number of axles, springs and tires

12. Mounting the equalizer beams on Hendrickson suspension below the axle housings:
    (a) keeps the beams out of the way
    (b) lowers the center of gravity for better stability.
    (c) protects the axle housings and springs.

13. In a four-spring Reyco suspension system what method is used to maintain suspension alignment and stability?

14. Briefly explain how the mounting of Rockwell spring suspension differs from Hendrickson equalizer beam suspension mounting.

15. Mack camelback spring suspension is mounted similar to:
    (a) Hendrickson suspension
    (b) Reyco suspension
    (c) Rockwell suspension

16. What method is used to maintain alignment in Hendrickson rubber block suspension?

17. What are the two purposes of the front rubber suspension units used on large mining trucks?

18. Hydro-air suspension cylinders are precharged with:
    (a) nitrogen
    (b) oxygen
    (c) hydrogen
    (d) carbon-dioxide

19. What is the advantage of air suspension? Where is it likely to be used?

20. What is the function of leveling or height control valves on air suspension?

21. The front of the axle housing on a machine using hydro-air suspension cylinders is supported by an ____________.

MAINTENANCE AND SERVICE REPAIR ON RIGID AND SPRING SUSPENSION

PREVENTIVE MAINTENANCE — LOADER, GRADER AND SKIDDER RIGID SUSPENSION

Although little maintenance is required on wheel loader, grader, and skidder rigid suspensions there are a few points of the suspension that should be checked during the daily walk around inspection of the vehicle. Prior to doing any checking take the following precautions:

Caution: To prevent personal injury, always lower all equipment with slight down pressure, stop engine, set parking brake and block or restrain machine before servicing it, unless otherwise specified. Install the safety bar or articulated machines.

Daily, Routine Checks on Rigid Suspension

1. Check the frame members, welded joints and brackets for cracks.
2. Remove any debris build-up at the pivot point of articulated machines or at steering axles.
3. Visually check for loose drive axle housing mounting bolts.
4. Visually check for loose wheel nuts. A streak of rust underneath a nut is an indication that it is loose.
5. Check tire condition and pressure.

Scheduled Maintenance on Rigid Suspension

Scheduled maintenance for rigid suspensions is a continuation of the daily checks, only a more thorough inspection of the overall frame and suspension component is undertaken. This inspection would generally be done at 500 to 1,000 hour intervals or every three to six months. Refer to service manuals.

Before beginning the inspection, the frame, drive housings and other related suspension parts should be thoroughly washed with a high pressure washer or steam cleaner. In fact, keeping the machine clean on a regular basis whenever possible is a good maintenance practice because it enables you to see minor problems in their early stages.

Scheduled maintenance on rigid suspension would include the following:

Caution: Never work on a machine until servicing safety precautions have been taken.

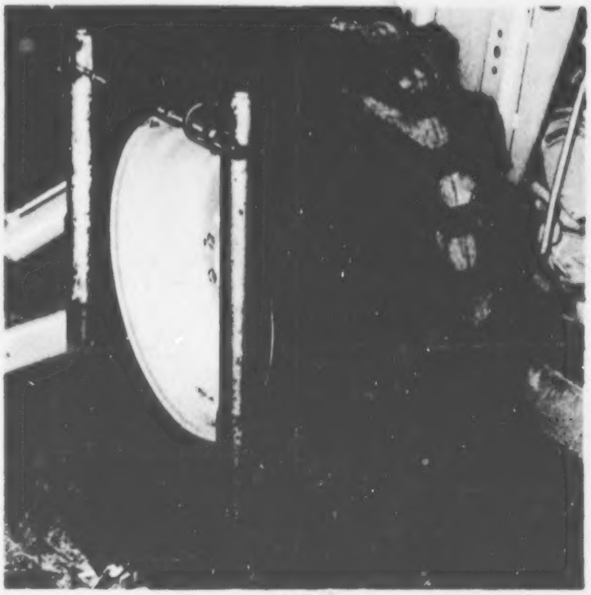
1. Thoroughly inspect the main frame, looking for weld cracks, broken welds, damaged brackets, cross members and reinforcing gussets. Check the bolster bushings and pins for wear or damage. Special attention should be given to hinge pin assemblies: be sure they are properly centered and seals and bushings are in good condition. Any frame damage should be corrected or repaired immediately. Note that most frames are made of a low-carbon, heat-treated steel that has added strength and hardness. This steel requires special welding procedures that should be undertaken only by a qualified welder.
2. To keep rust and corrosion to a minimum, periodic painting of abrasions and bare metal is recommended.
3. Check for loose axle housing mounting bolts. Retorque any loose bolts to specifications.
4. Lubricate pivot points: bolster pins, upper and lower articulation pins, front axle pins. Check the service manual for grease fitting locations.
5. Some articulated frame pivot points have adjusting procedures. See Service Manuals.
6. Check tire condition and pressure.
7. Check for loose wheel nuts by retorquing them to specifications.

SERVICE REAPIR ON RIGID SUSPENSION (GRADERS, LOADERS, AND SKIDDERS)

Removal of the suspension components from a machine with rigid suspension essentially involves removing the drive axle housings for wheel loaders and skidders, and the tandem housings for graders. A steering axle may also have to be removed from some smaller loaders. Removing these components is similar to removing crawler undercarriage components in that they are large, heavy parts that require suitable jacking and lifting equipment and solid blocks or stands to support the machine. Safety must be foremost in mind when doing the job.

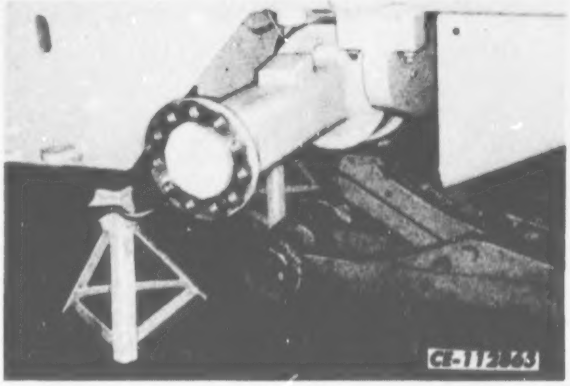
REMOVING AND INSTALLING LOADER OR SKIDDER SUSPENSION

1. To remove the axle housings, it may be easier to first remove the working attachment, i.e., the bucket or blade.
2. The general sequence of procedure to remove the axles is as follows:
   (a) Clean the suspension components and prepare the macnine for maintenance.
   (b) Safely jack the machine until the wheels clear the ground, and then block it.
   (c) It is easier for the axles to clear the frame if the wheels are taken off. To remove wheels use a wheel dolly (Figure 6-263) or suitable lifting equipment.
   (d) Disconnect drive shafts and brake lines (if applicable). Cap the lines with correctly sized plastic caps, or, if these aren't available, use tape or rubber stoppers. Never use rags because they may introduce contaminants into the system. Tag the lines.
   (e) Place a wheel jack under the axle housing (Figure 6-264).
   (f) Remove the bolts that attach the housing to the frame, lower the housing clear of the machine, and wheel it out on the jack.



(6-263)

Courtesy of Massey Ferguson Inc.

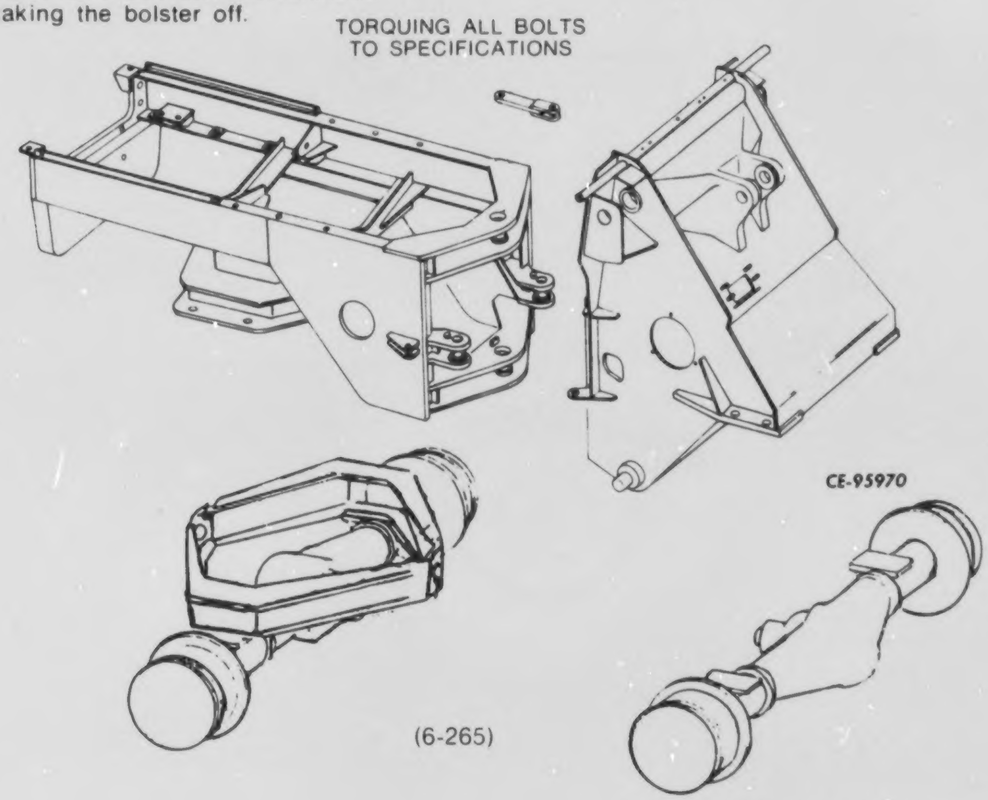


(6-264)

AXLE MOUNTING AND JACK POSITION

Courtesy of International Harvester

Figure 6-265 shows the axles removed from a loader. In this example the bolster and rear axle are taken off together. However, the axle can also be removed without taking the bolster off.

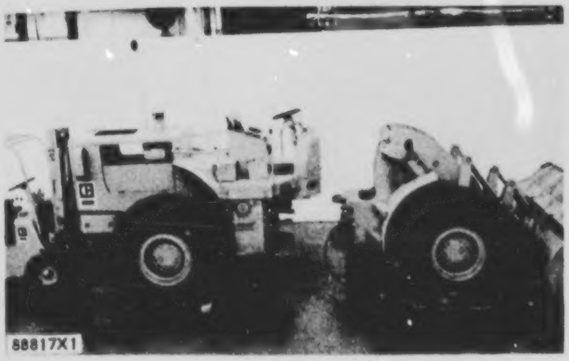


(6-265)

Courtesy of International Harvester

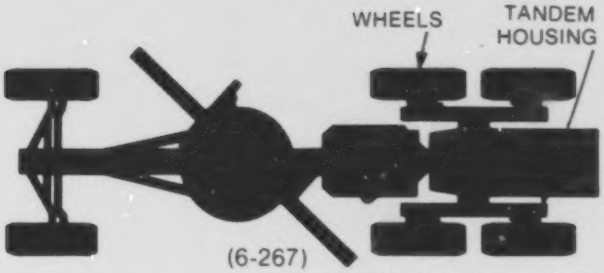
3. Often, articulated wheel loaders have a counter weight on the rear main frame. Should it be necessary to separate the two frames of such a machine, be sure the rear section is adequately supported. In Figure 6-266 a fork lift is used to hold up the weighted end. The front frame should also be supported and the wheels blocked.

   Also when separating articulated machines, hydraulic lines will have to be disconnected. Make sure that pressure in the system is neutralized before disconnecting the lines. Cap and tag the lines.



(6-266)

Courtesy of Caterpillar Tractor Co.



(6-267)

Courtesy of Caterpillar Tractor Co

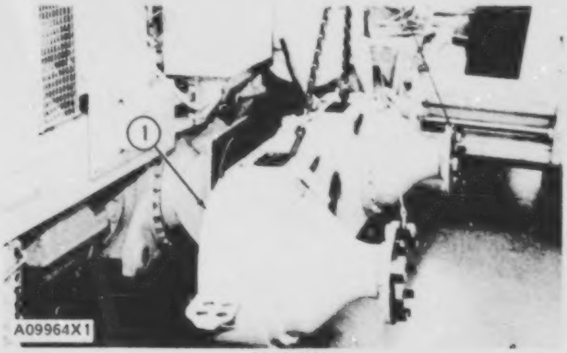
Removing Grader Tandem Housings

On a grader the wheels and tandem housings make up the complete rear suspension (Figure 6-267). The tandem housings oscillate parallel with the frame from a pivot point at the center of the housings. The housings are removed at this point (Figure 6-268). A more detailed view of tandem housing removal can be seen in the section on wheel final drives.

Service Repair — Grader Suspension

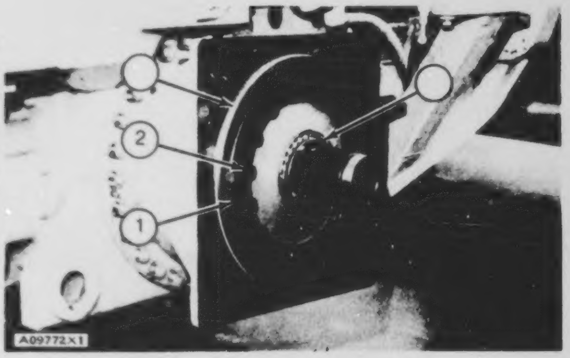
The two pivot points of a grader carry the brunt of the machine's weight, and it logically follows that these points will need service repair. Drive axle spindles and bearings also need repair.

There are various designs used by manufacturers to attach the tandem housings to the final drives in such a way that they can oscillate. The Caterpillar design shown in Figure 6-269 is called an oscillation housing. When the tandem housing is lifted free of the machine, the oscillation housing remains attached to the final drive housing. The oscillation housing is supported on the final drive housing by bearings and is held by the retainer (1) and bolts (2) in Figure 6-269. When these bolts and retainers are removed, the oscillation housing can be pulled free from the final drive housing.



(6-268)

Courtesy of Caterpillar Tractor Co.



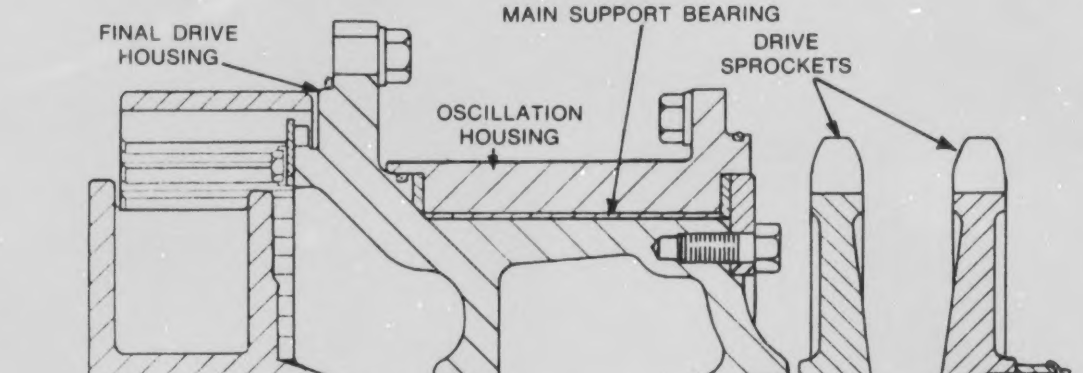
(6-269) 1—Retainer. 2—Bolts.

Courtesy of Caterpillar Tractor Co.

Service Repair — Loader and Skidder Suspension

Repairs to loader and skidder rigid suspension are mainly concerned with damaged mounting brackets and pads, worn bolt holes, cracks in the frame, and cracked welds on gussets and bracket cross members. On articulated machines the center pin and bushing or bearing will wear and require servicing repair or replacement. The bolster must also be checked for cracks, and the bolster pivot pins and bushings will also wear and require servicing (replacing).

The oscillation bearing, thrust rings and O-ring seals are replaced on this assembly. Prelubricate the new bearings, thrust rings and O-rings with a little oil. Practise absolute cleanliness on reassembly. When installing the oscillating housing on the final drive housing, be careful not to damage the O-ring seals. Figure 6-270 shows a cross-section of the oscillation housing attached to the final drive housing.


FINAL DRIVE HOUSING
MAIN SUPPORT BEARING
DRIVE SPROCKETS
OSCILLATION HOUSING
THRUST BEARINGS
TANDEM HOUSING BOLTS TO THIS FACE
OSCILLATION HOUSING O-RING SEAL

(6-270)

Courtesy of Caterpillar Tractor Company

QUESTIONS — RIGID SUSPENSION MAINTENANCE AND REPAIR

1. Prior to doing any preventive maintenance checking on an articulated machine, what precaution must be observed?
2. Why is it a good practice to clean a machine on a regular basis?
3. What are the pivot points that may need lubrication on a rigid suspension system?
4. If it is necessary to separate the two frame halves on an articulated loader, what are the precautions that should be taken?
5. List the kinds of things that may need repair on rigid frame suspension.
6. What parts are usually replaced on a grader oscillation housing?

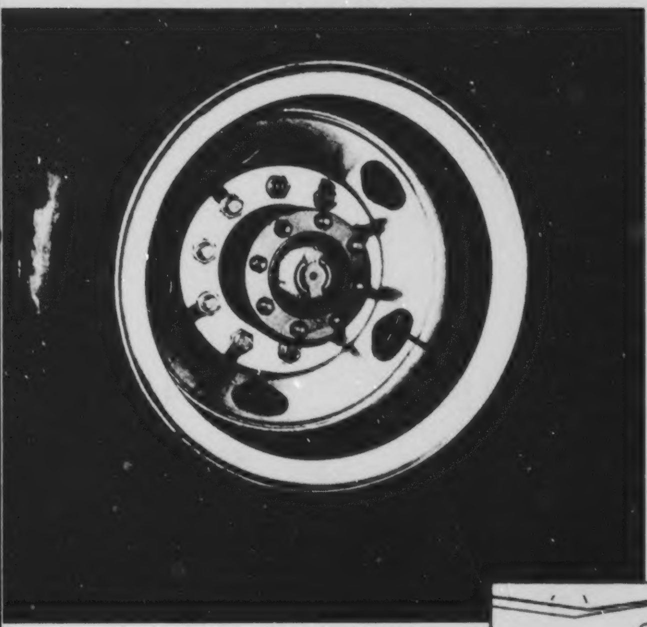
SERVICE OF TRUCK FRAMES AND REAR SUSPENSION

DAILY, ROUTINE MAINTENANCE ON TRUCK REAR SUSPENSION

A thorough daily, routine maintenance check of a highway truck rear suspension would include:

Caution: Before doing a daily, routine check, park the truck on level ground, turn the engine off and set the parking brake.

1. Check the condition and pressure of the tires. (See Tire section, Daily, Walk-Around Checks). Remember, inspecting truck tires is the single most important check for highway safety.
2. Visually check for loose wheel nuts. As mentioned earlier rusty marks around nuts indicate looseness (Figure 6-271).



(6-271)

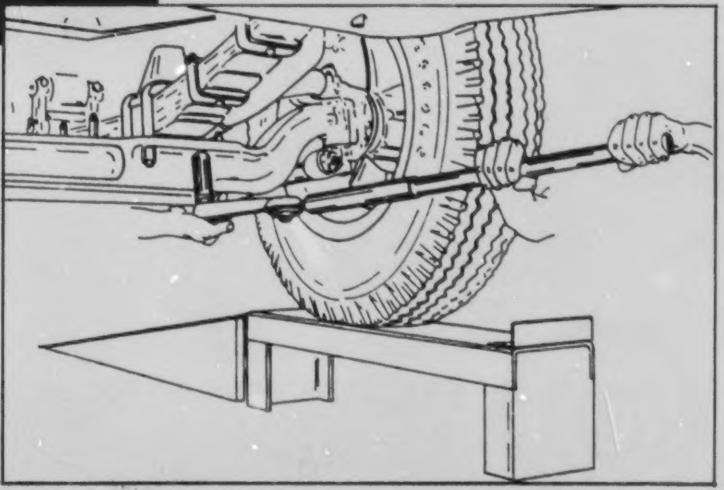
RUST STREAKS FROM STUD HOLES CAUSED BY LOOSE CAP NUTS

Courtesy of Budd

3. Visually check the frame for loose bolts and rivets and for cracks. Also check for loose components.
4. Visually check for loose torque arm bushings and attaching bolts. Check the condition of torque arms, spring saddles, walking beam bushings.
5. Check the condition of the shock absorbers. Look for any leakage.
6. Check the springs for cracked or broken leaves, and for worn shackle pins.
7. Check for loose U-bolts.

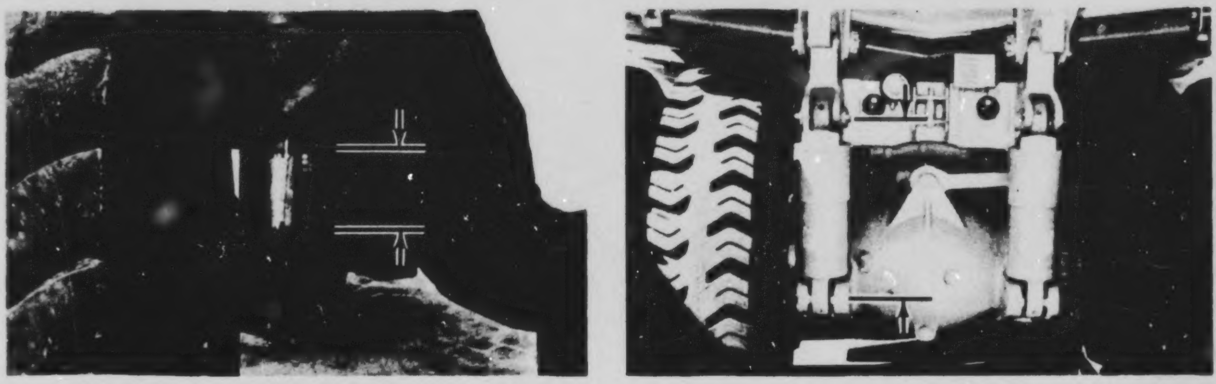
   Loose U-bolts are often the cause of leaf-spring breakage, axle misalignment, hard steering, and abnormal tire wear. Tighten U-bolts (Figure 6-272) after the first 500 miles (800 km) on a new vehicle as the springs settle and cause U-bolt tension to slacken. Check the U-bolt tension of on-highway vehicles every 25,000 miles (40,000 km). Check off-highway vehicles weekly. The vehicle should be loaded to its normal gross weight when tightening the U-bolts. The use of a torque wrench is highly recommended. If U-bolts or nuts need replacing, do not risk an accident by using common U-bolts or standard nuts. Use only U-bolts and nuts of SAE Grade 8 specifications.

8. On off-highway trucks that have hydro-air suspension, check the suspension cylinder piston extension (Figure 6-273). The check should be made when the vehicle is level, empty and has come to a gradual stop. Allowable tolerances are given in service manuals. Report if the piston extension is not within the acceptable range. Also check the cylinders for leakage.



(6-272)

Courtesy of Kenworth Truck Company



FRONT CYLINDERS (6-273) REAR CYLINDERS

Courtesy of Caterpillar Tractor Co.

SCHEDULED MAINTENANCE OF TRUCK REAR SUSPENSION

In truck service manuals, scheduled maintenance will mainly consist of lubrication schedules. However, service people, should do more on suspensions than just perform lubrication service. They should be observant, always looking for minor problems before they develop into major ones.

An example of the lubrication schedules for a heavy duty, off-highway truck is given in Figure 6-274. Note that the severity of off-highway operating conditions often demands more frequent lubrication than on-highway operation. Whereas off-highway wheel bearings are packed every 10,000 miles, on-highway bearings are packed at approximately every 25,000 miles.

At the same time that the lubrication is done, all the points mentioned in daily, routine maintenance should be checked. It is a good idea to clean the suspension components before undertaking the inspection.

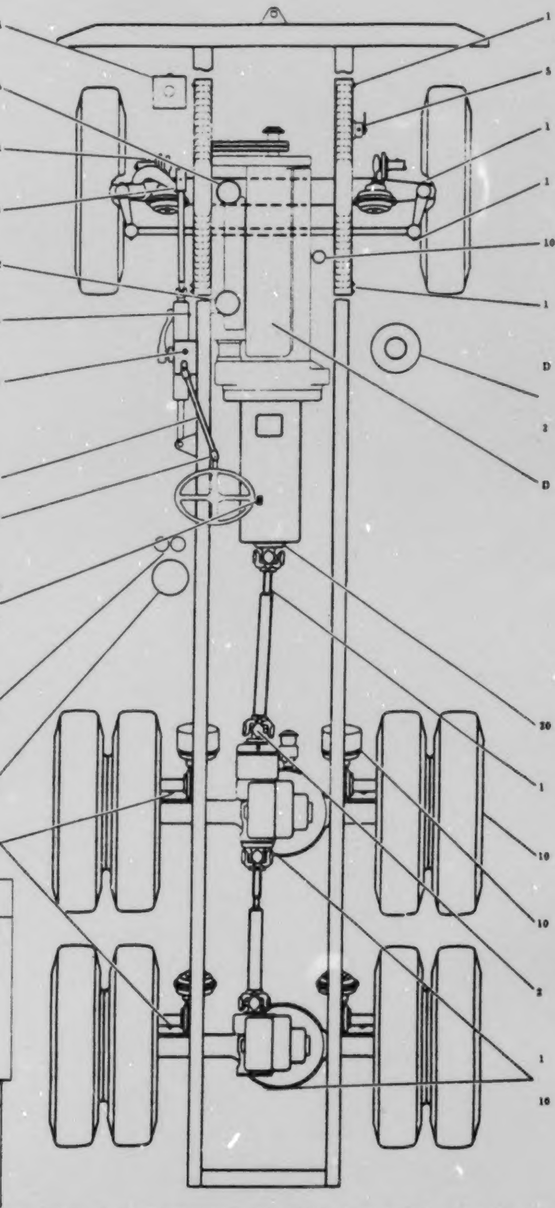
KENWORTH MAINTENANCE MANUAL | PREVENTIVE MAINTENANCE

LUBRICATION CHART

HEAVY DUTY OFF-HIWAY

ALLISON TORQMATIC TRANSMISSION

	LUBRICANT	INTERVAL
POWER STEERING RESERVOIR Check Oil Level (Change oil annually)	C-2	1
POWER STEERING FILTER Change Element Annually	–	A
FRONT BRAKE CAMSHAFTS Lubricate Sparingly (One fitting each side)	Ⓒⓛ CL	1
DRAG LINK (One fitting each end)	CL	1
ENGINE LUBRICATING OIL FILTER (Full-flow type) Change Bag	–	2
PITMAN ARM Lubricate Sparingly	CL	1
STEERING GEARBOX Check Oil Level (SAE 90 Gear Oil)	GO	1
STEERING SLIP JOINT	CL	1
STEERING UNIVERSAL JOINT SAE 140 Gear Oil (One fitting each end)	GO	2
HYDRAULIC TRANS. & CONVERTER Check Oil Level Daily	C-2	D
Drain and Refill Remove and Clean Sump Strainer Use Hydraulic Transmission Fluid Type C-2	C-2	20
FUEL FILTERS Drain One Cup of Fuel	–	D
Change Elements	–	10
ENGINE OIL FILTER (By-pass type) Drain Filter	–	2
Change Element	–	4
REAR BRAKE CAMSHAFTS Lubricate Sparingly (One fitting each brake, total 4 fittings)	CL	1



INTERVAL	LUBRICANT	
1	CL	**SPRING PINS** (One fitting each side)
5	SA	**SHOCK ABSORBERS** Check Oil Level and Fill
1	CL	**KING PINS** (Two fittings each side)
1	CL	**TIE ROD ENDS** (One fitting each side)
10	–	**ENGINE WATER FILTER** Change Element and Replace Corrosion Plates when Pitted
1	CL	**SPRING SHACKLE PINS** (Two fittings each side)
D	–	**ENGINE AIR CLEANER** Check Pan (Check daily or more often when operating in severe rain or dust conditions.)
2	–	Maximum Change Interval
D	*	**ENGINE CRANKCASE** Check Oil Level Daily * Refer to engine manual.
20	L	**SPEEDOMETER ADAPTER & DRIVE CABLES**
1	CL	**PROPELLER SHAFT SLIP JOINTS** (One fitting each propeller shaft, total 3 fittings)
10	WB	**WHEEL BEARINGS** Clean and Repack Both Front and Rear Axles.
10	EO	**SPRING BRAKES** Add SAE 20 Engine Oil to Cylinders
2	GO	**PROPELLER SHAFT UNIV. JOINTS** SAE 140 Gear Oil (One fitting each universal joint, total 6 fittings)
1	GL-5	**REAR AXLES** Check Oil Level
10	GL-5	Drain, Flush & Refill (Fill housing to level of fill hole with SAE 140 GL-5 hypoid gear lubricant. Use SAE 90 oil when operating temperature is below 0°F.

KEY	
C-2	Hydraulic Transmission Fluid Type C-2
BB	Ball Bearing Grease, Sodium Soap Base
	High Temperature Grease
CL	Chassis Lubricant
EO	Engine Oil
GO	Gear Oil, Straight Mineral
L	Lubriplate Aero or equivalent
GL-5	Gear Lubricant GL-5 (per form 18076E)
WB	Wheel Bearing Grease
SA	Shock Absorber Fluid, Heavy Duty

INTERVAL	
D	Daily
1	1,000 Miles
2	2,000 Miles
5	5,000 Miles
10	10,000 Miles
20	20,000 Miles
A	Annually

THIS LUBRICATION CHART APPLIES TO KENWORTH HEAVY DUTY OFF-HIWAY MODEL L-924, L-824, 848, ETC.

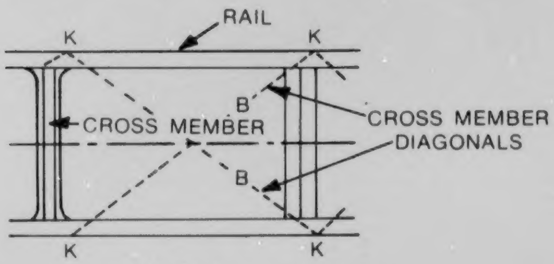
Courtesy of Kenworth Truck Co.

SERVICE REPAIR OF TRUCK FRAMES AND REAR SUSPENSION

Frame Alignment

Frames can become misaligned, although usually misalignment will occur only as a result of an accident. When a frame is misaligned the cross members are out of square with the rails. The cause can be a bent or twisted rail or one of the rails could be pushed forward or backwards. A vehicle with an obviously misaligned frame would be sent to a frame shop for repairs, or to have one or both of the rails replaced (on larger trucks).

Frame alignment can be checked by dropping a plumb bob from the frame to the floor at points K in Figure 6-275. If the diagonals are not the same or within allowable tolerances of one another, that section of the frame is misaligned. The use of the plumb bob to transfer frame points to the floor is necessary because all the parts and pieces attached to the frame make it impossible to put a square against the rail and cross member or to measure the diagonals with a tape.



(6-275)

Frame Repair

The following material about frames, and frame repair, is used courtesy of International Harvester.

Since frames must keep the major components of a vehicle in their relative positions, they should be kept in good condition. Truck frames are manufactured with frame rails of either non-heat-treated steel, heat-treated steel or aluminum alloy. It is important to be able to recognize the different frames because they have different repair procedures.

No difficulties should be encountered in identifying aluminum alloy frames because the side rails and cross members are made of thicker material than are the components of a steel frame of comparative size. If there is any doubt, use a file to check the material's hardness or color.

There are several methods of identifying heat-treated frame rails. The most common is a stencil marking on the inside middle section of the rail or a stencil mark on one of the cross members. The stencil notes that the rail is heat-treated and rail flanges must not be drilled or welded. It is a caution against welding additional brackets cross members, or full length reinforcement rails to the frame. Minor repairs to heat-treated frames, as shown further on in this section, are acceptable.

A second method of identifying heat frame rails is to have small patches covering "Brinell" test marks along the inside (web) of the rail. These patches are found about every three or four feet. The patch can be removed to expose the "Brinell" marking. A third method is to stamp "H" for heat-treated on the upper face of the rail flange about three inches from the rail end.

REPAIR ON NON-HEAT-TREATED FRAMES

Cutting

Whenever it is necessary to cut the frame, the side rail should be cut at an angle of 45 degrees. This method distributes the cut and weld over a greater area than a cut made at right angles.

Reinforcing

Reinforcements may be made with flat, channel or angle stock. Reinforcement thickness should not exceed the original side rail thickness. Because of difficulties encountered when inserting channel reinforcements into the frame side rails, the use of angle reinforcements is acceptable. When ever possible, the reinforcement should extend from the front axle to slightly beyond the rear spring front mounting bracket. If a rail is damaged beyond repair, or if it is too costly to repair, the complete rail may be removed and be replaced with a new one. (New rails may also be installed on heat-treated and aluminum alloy frames.)

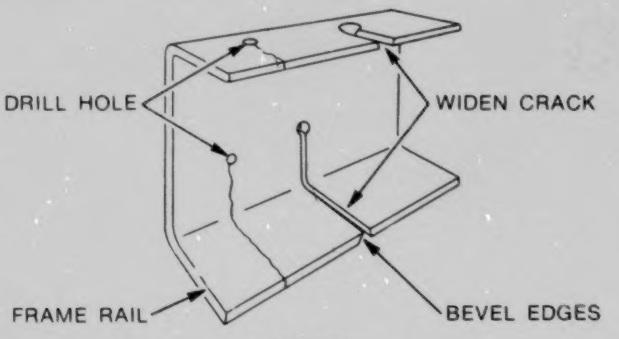
Hot rivets are acceptable to attach reinforcements, and they can be driven with hand tools. Cold rivets should only be used when you have tools of sufficient power to properly set the rivets. The diameter of the rivets should be 50 to 100 percent of the total thickness of the plates to be riveted.

Welding

Electric arc-welding is recommended for all frame welding. The reinforcements should be welded to the frame after the reinforcements are riveted. All unused holes should be filled with welding material. The welding-rod should have a substantial amount of the same material that is used in the frame.

Preparation Of Frame For Repair

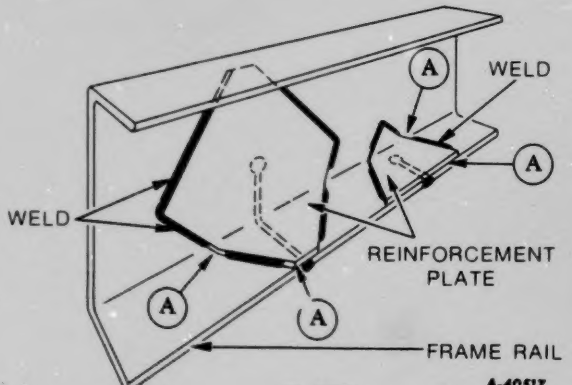
Before welding the reinforcement to the cracked section of the frame side rail, certain preparations are necessary to insure strength and stability. To prevent further spreading of the crack, a hole should be drilled at the starting point of the crack (Figure 6-276). Widen the crack its full length using two hacksaw blades together. Groove or bevel both sides of the crack so that the weld establishes a solid contact between the reinforcement and the frame side rail. The grooving can be done with a grinder or a cape chisel.



(6-276)

Courtesy of International Harvester

When welding reinforcements it is important that you do not weld into the corners of the frame or along the edges of the frame side rail flanges, points "A" in Figure 6-277. Welding at these points tends to weaken the frame and encourages the development of new cracks. Note the shapes of the reinforcements and the angles of the welds. Always avoid welds made square with the side rail, either on webs or flanges. When welds are made at an angle of at least 30 degrees from square, there is less possibility of setting up dangerous stress concentrations in the rail.



(6-277)

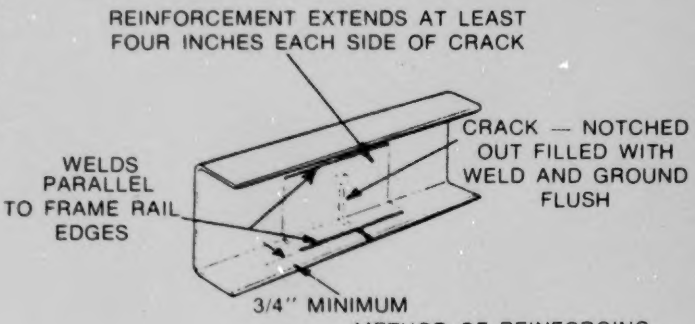
Courtesy of International Harvester

Frame Straightening

Use of heat is not recommended when straightening non-heat-treated frames because heat weakens the structural characteristics of frame members. All straightening should be done cold. Frame members (except aluminum) which are bent or buckled sufficiently to show cracks or weakness after straightening, should be replaced or reinforced. Note that when replacing a rail, never intermix the frame material; the new rail material must match the old.

REPAIR OF HEAT TREATED FRAME

Heat treated frames require special welding preparations and techniques. Consult the service manual or welding manual for the correct heat-treated metal welding practices. Welds on heat-treated material tend to reduce physical properties in the area affected by weld heat. Because of this, it is recommended that reinforcements be shaped so that all welds are parallel, rather than perpendicular, to the frame rail edges (Figure 6-278). Welds perpendicular to the flange edges will reduce the carrying capacity of the rail.

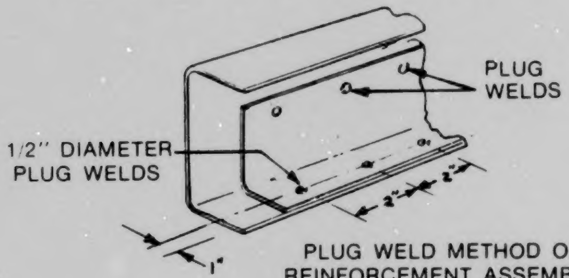

REINFORCEMENT EXTENDS AT LEAST FOUR INCHES EACH SIDE OF CRACK
CRACK — NOTCHED OUT FILLED WITH WELD AND GROUND FLUSH
WELDS PARALLEL TO FRAME RAIL EDGES
3/4" MINIMUM

METHOD OF REINFORCING CRACK IN FRAME

(6-278)

Courtesy of International Harvester

Wherever possible, it is recommended that plug welds (Figure 6-279) be substituted for edge welds when attaching the reinforcement to the side rail. Plug welds offer the advantages of a reduced heat-affected zone, increased flexibility and reduced stress concentrations. When using this method, one half inch (minimum) diameter holes should be drilled and beveled in the reinforcement at two inch center to center distances. At no time should these holes be drilled in the frame rail being repaired. The reinforcement should then be placed over the repair point on the rail and the holes filled with weld material. Again a minimum dimension of three-quarter inch should be maintained between the weld and the edge of the side member flange.



PLUG WELD METHOD OF REINFORCEMENT ASSEMBLY

(6-279) MT-4986

Courtesy of International Harvester

Full Length Reinforcement

When heat-treated frames are to be reinforced over a greater portion of their length, frame channel reinforcements should be installed using bolts. Bolts of high strength material conforming to SAE Grade 5 or better should be used. The bolts and nuts should be inspected periodically and kept tight since the strength of the reinforcement depends somewhat on the maximum clamping force between the members.

Frame Straightening

When heat-treated frame rails have been bent or twisted, they should not be heated for straightening. Straightening should be done with the frame rails cold. Heating is likely to destroy the rail temper in localized areas and cause rail failures.

Repairs On Aluminum Alloy Frames

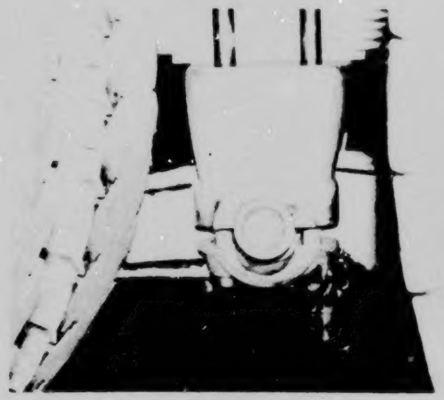
The cutting of aluminum alloy frame rails for repair or reinforcement is not approved because aluminum rails cannot be welded without losing their original strength. Also heat is not recommended for straightening these rails. Cracked or fractured aluminum frame rails should always be replaced.

SERVICE REPAIR ON SPRING SUSPENSION

Removal

Below are general procedures for removing Hendrickson spring suspensions. Similar procedures are used to remove other spring suspensions such as Reyco and Mack. See Service Manuals for exact procedures. The entire suspension is removed here, but if need be, the torque arms, springs, equalizer beams, hangers may be taken out individually.

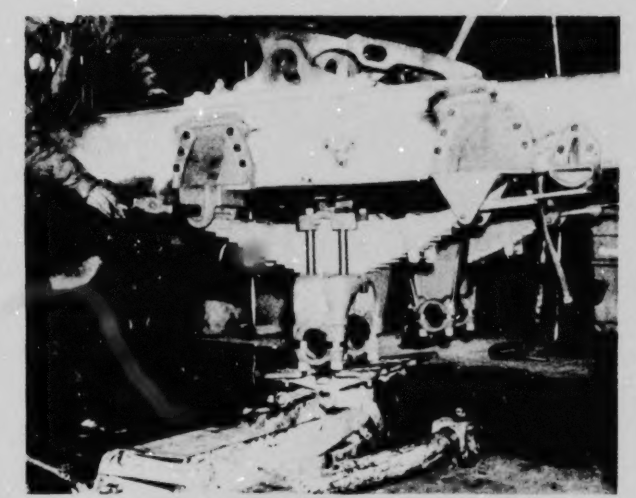
1. Block the tires on both axles and disconnect the brake lines from the axles.
2. Disconnect the drive axles at the universal joints either by unbolting the companion flanges or by disconnecting the universal joint yokes.
3. The suspension is taken out in two stages. In the first stage the equalizing beams are unbolted from the springs (Figure 6-280) and the torque arms are disconnected at the axle brackets. Care should be taken when disconnecting the torque rods, since the axle assemblies may be free to roll or pivot at the equalizer beam ends. The frame is then lifted with a hoist, and the equalizer beams and axles are rolled out on the wheels.



(6-280)

Courtesy of Hendrickson Manufacturing Ltd.

4. The frame is then blocked. A floor jack is placed under the spring and saddle assembly (one at a time), the spring pin is removed, and the spring is rolled out on the jack (Figure 6-281).



(6-281)

Courtesy of Hendrickson Manufacturing Ltd.

Cleaning and Inspection

Clean all dirt from the suspension parts and inspect them carefully for cracks or damage. Magnaflux or fluorescent equipment may be used to inspect the parts. Inspect the rubber bushings for damage or deterioration. Petroleum products usually will not harm the Hendrickson equalizing beam center bushings because they are not in an exposed position. However, the outer edges of the beam's end bushings are exposed and will deteriorate from continuous oil saturation. If the suspension has been in service for a long period of time, it is advisable to replace all bushings.

Most repairs to spring suspension systems consist of replacing worn or damaged parts. The major item that will concern the serviceman on equalizer beam suspension is removal and replacement of the rubber bushings. While bushings have long life, they eventually deteriorate and need replacing. Special service tools for replacing bushings on equalizing beams are made; they are the best tools for the job, but are not absolutely necessary. If press equipment is available, standard steel tubing having diameters to match the bushing sleeves (metal bands surrounding the rubber bushings) can be used as adapters for removing and installing the bushings. Pressures required to remove the bushing and sleeve assemblies will generally be between 35 to 50 tons.

Note: Do not use a cutting torch to aid in the removal of bushings from equalizer beams. The beams are heat-treated and the heat from the torch will weaken them. Repair of spring suspension parts are discussed below.

Spring Hangers

Check the condition of spring hangers. Also check the spring pin holes on the front hangers and the cams on the rear hangers. If the hangers are worn excessively, they should be replaced. At major overhauls, spring hanger pins and spring eye bushings (if the springs are to be reused) should be replaced.

Springs

Putting aside the fact that springs can be broken by loose U-bolts, springs eventually wear out due to metal fatigue. Fatigue cracks start at a scratch, notch or rust spot and progressively deepen and lengthen. Some of the factors affecting fatigue (i.e., spring life) are: vehicle gross weight, type of load, road conditions, vehicle speed, and suspension maintenance practices.

Before disassembling the spring, mark with a chalk or grease pencil down one side of the spring so that you know the original position of the leaves on reassembly. To disassemble the spring, place it in a vise (small springs) or an arbor press (large springs) next to the center bolt.

The problem when inspecting springs is to determine if it is better to repair or to replace broken springs. Consideration should be given to spring mileage, number of previous repairs and relative cost of repairs compared to the cost of new springs. If one spring is replaced, it is recommended that the other be replaced as well, otherwise the deflection would differ on each side. The same can be said for shock absorbers: replace them in pairs. Below is a guideline to use when considering the question whether to repair or replace springs.

When To Repair Broken Springs

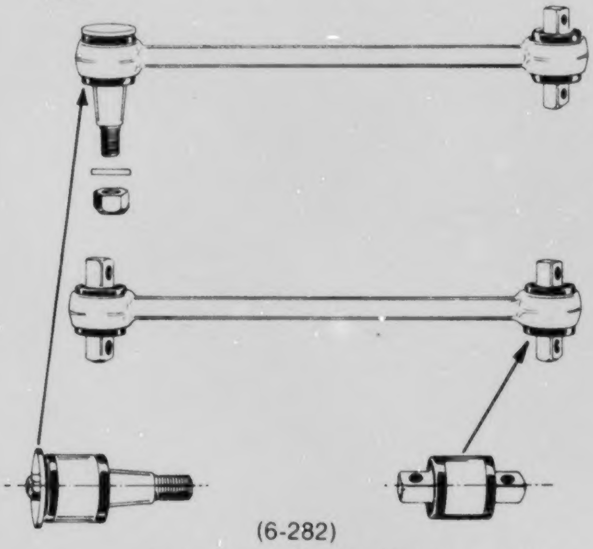
1. If the spring has been repaired not more than once already.

2. If spring mileage is less than half of the spring's normal life (approximately 200,000 highway miles or 75,000 off-highway miles).
3. If the cost of repairs is less than two-thirds the cost of new springs.

If the converse of any of these three points is true, replace the springs.

Torque Rods

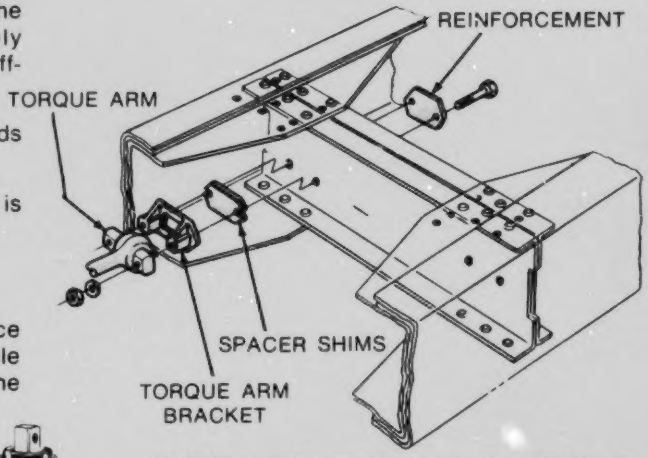
Torque rod ends deteriorate after long service life. Many torque rod models have replaceable ends (Figure 6-282) that are press fit into the rods.



(6-282)

Courtesy of Hendrickson Manufacturing Ltd.

Upper torque rods are adjustable or have adjusting shims either between the rod and its mounting bracket or between the mounting bracket and the frame cross member (Figure 6-283). It is essential for drive line alignment (i.e., alignment of companion universal joint flanges or yokes) that torque rods be reinstalled in the exact position from which they were removed. Adjustable rods should not have their adjustments altered, and shim pack thickness should be identical. The importance of having torque rods properly installed and in good condition cannot be over-emphasized.



(6-283) VIEW IN DIRECTION OF ARROW Y

Courtesy of Ford Motor Company

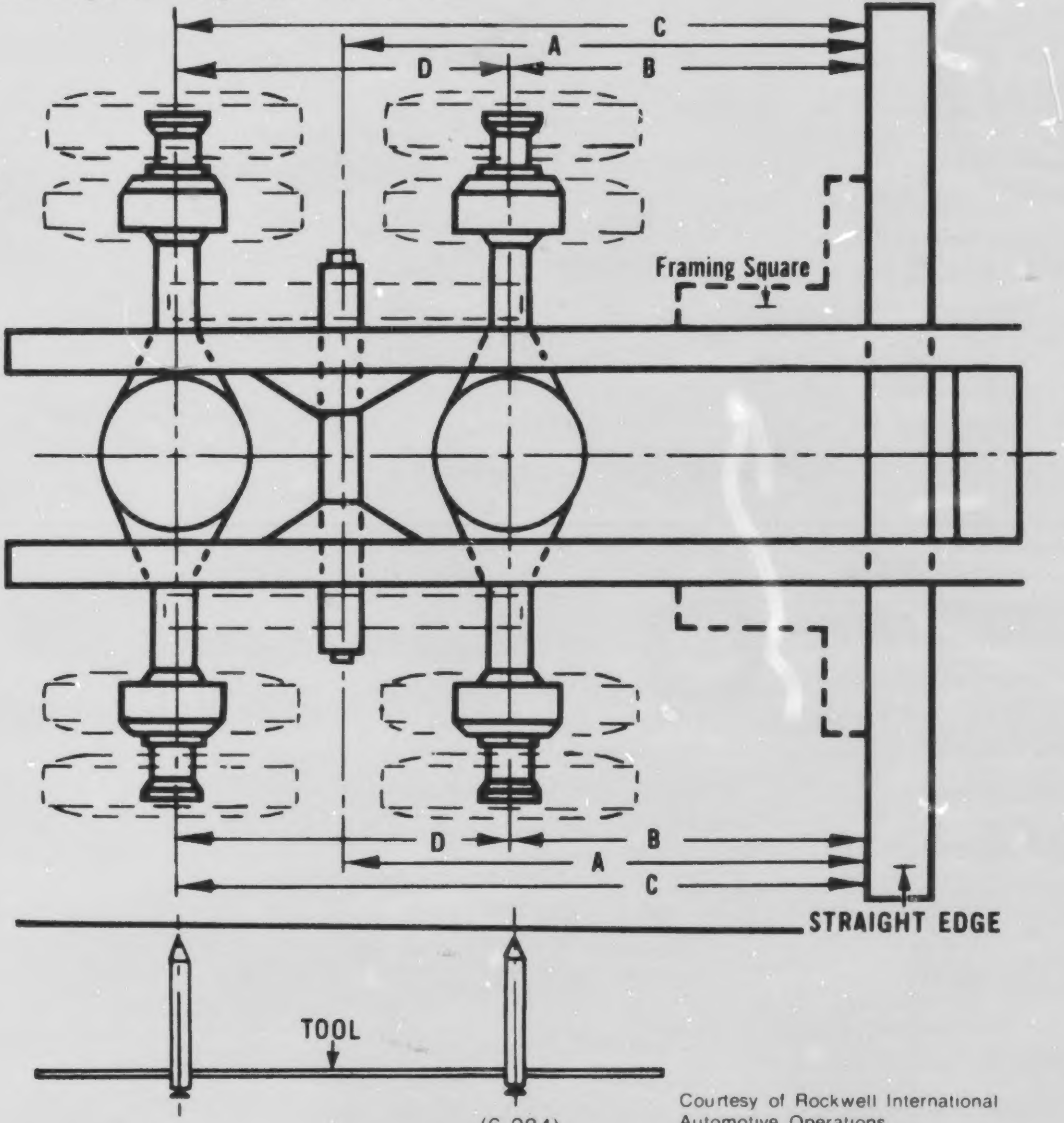
AXLE OR BOGIE MISALIGNMENT

When a vehicle has done many miles of service, chances are axle misalignment will exist due to normal wear of the suspension parts. If, during the scheduled maintenance checks, accelerated or abnormal tire wear is noted, the rear suspension alignment should be checked. Axle housing(s) should be square with the frame and tandem axles parallel with one another. Misalignment should be corrected immediately because it can greatly add to the operating costs of the vehicle through accelerated tire wear. Vehicles that have had their rear suspension rebuilt should also be checked for correct axle alignment.

Some suspension systems are more likely to become misaligned than others due to their number of moving parts. However, misalignment usually occurs only after many miles or hours of service. Some systems, e.g., Rockwell, have a means of correcting misalignment, while others such as Hendrickson don't. Alignment problems with Hendrickson suspension usually indicate a major suspension overhaul is needed.

Checking Alignment

A common method (courtesy of Rockwell International) for checking bogie alignment is given below. This method involves squaring and clamping a straight edge to the frame and then measuring from the straight edge to each side of the axle (Figure 6-284). The measurements should be the same (or within allowable tolerances) if the axle is aligned with the frame. Note that the straight edge should extend at least one foot further than the overall tire width. The straight edge method is used here to check the alignment of tandem axles, but it may also be used to check single axle alignment, front or rear.



(6-284)

Courtesy of Rockwell International Automotive Operations

1. Measure distances (A) from the straight edge to the connecting tube centers. Tolerance: 1/16". This measurement tells you if the suspension assembly is parallel with the frame.
2. Measure distances (B) from the straight edge to the back rear axle center. Tolerance: 1/8". This measurement tells you if the back rear axle is perpendicular with the frame.
3. Measure distances (C) from the straight edge to the front rear axle center. Tolerance: 1/8". This measurement tells you if the front rear axle is perpendicular or aligned with the frame.
4. Measure axle center distances (D) to see if the axles are parallel. Tolerance: 1/4". Note the tool that is used to measure the axle centers.

If misalignment is found, first check to see that it is not caused by:

- — bent axle housings
- — frame damage
- — wheel bearings

If it is not, then refer to the service manual for the procedures to correct the misalignment. Some faulty alignments may be corrected by simply making adjustments, while others will require repair or replacement to correct such things as loose bolts, elongated holes in the frame support and connecting tube brackets, and worn torque rod ends. Service manuals often give a list of likely causes of misalignment. Check through this list carefully, because often corrective action can be made on the suspension without having to do a complete rebuild.

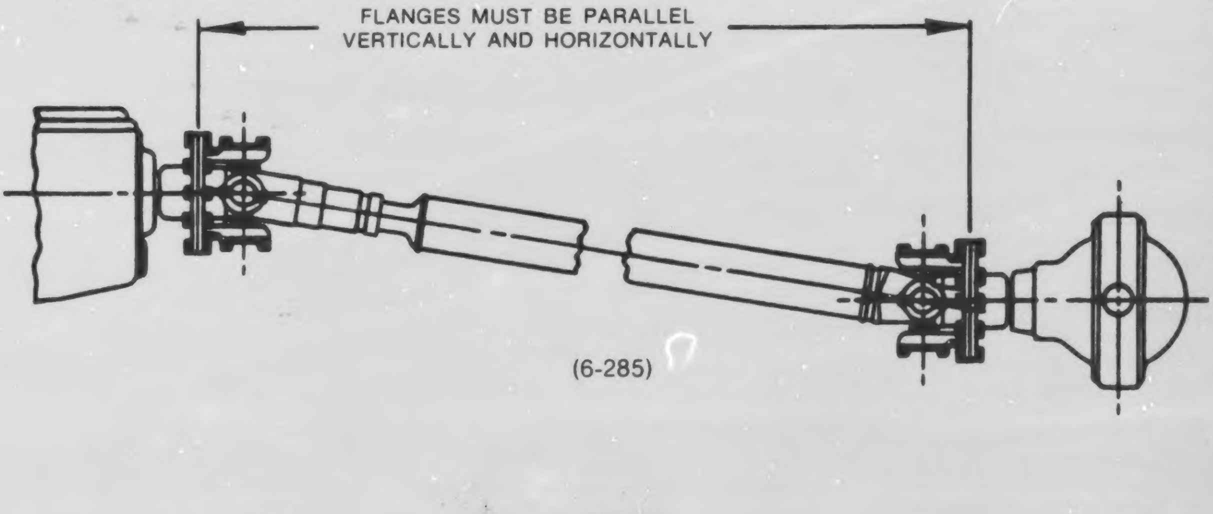
Universal Joint Companion Flanges

A very important adjustment related to rear suspension is the parallel alignment of the universal joint companion flanges (Figure 6-285). Removal and installation of the rear suspension assembly or the upper torque arms can throw out the universal flange alignment if not done correctly. A one degree tolerance is all that is allowed.

When removing shimmed torque rods, carefully note the number or size of the shims and reinstall the rods with exactly the same size shim pack. When removing an adjustable torque rod, be careful not to disturb the threaded adjustment; the adjustment must be in exactly the same position as when the rod was removed.

Apart from improperly installed torque arms, universal misalignment on tandem axles can also be caused by worn torque arms. To correct the misalignment, torque rods have to be adjusted to tilt the axle up or down. Depending on the type of torque rod, adjusting the rod involves: (1) adding or taking away shims, (2) adjusting the rod itself or (3) obtaining a new rod of the correct length. An apprentice should not attempt to correct universal misalignment unless under the guidance of a journeyperson.

Note that misalignment of the universal companion flanges or yokes on single axle trucks is not usually a problem because spring saddles are solidly fixed to the housing and the fronts of the rear springs are attached to the frame by shackle pins.



(6-285)

SERVICE REPAIR OF HYDRO-AIR SUSPENSION CYLINDERS

Special safety precautions must be practised when working with gas charged cylinders.

Warning: Do not attempt to check the oil in a suspension cylinder until all the nitrogen pressure has been released. Do not, under any circumstances, remove valves or plugs from the cylinder unless the rod is fully retracted and all the nitrogen pressure released. Do not stand under the vehicle when testing or adjusting the suspension cylinder because the rod can move suddenly causing the overhead clearance to quickly change.

Note the following points about hydro-air suspension:

1. There are four cylinders, two at the front and two at the rear. Each cylinder operates independently.
2. Binding can occur in diagonally opposed cylinders if one of the cylinders is low.
3. Procedures for removing the front and the rear cylinders is similar.
4. Repair of hydro-air cylinders may or may not be done in a shop. If a shop is frequently working on large off-highway vehicles using hydro-air suspension, they will probably rebuild suspension cylinders.
5. The information here does not deal with rebuilding the cylinders, but rather with (1) bleeding the nitrogen charge (2) checking/filling the oil (3) charging with nitrogen and (4) removing and installing the cylinders.
6. Removing and installing hydro-air cylinders is similar to the procedures to remove and install rubber cushion suspension cylinders except that no gas charge is involved.

Bleeding The Nitrogen Charge

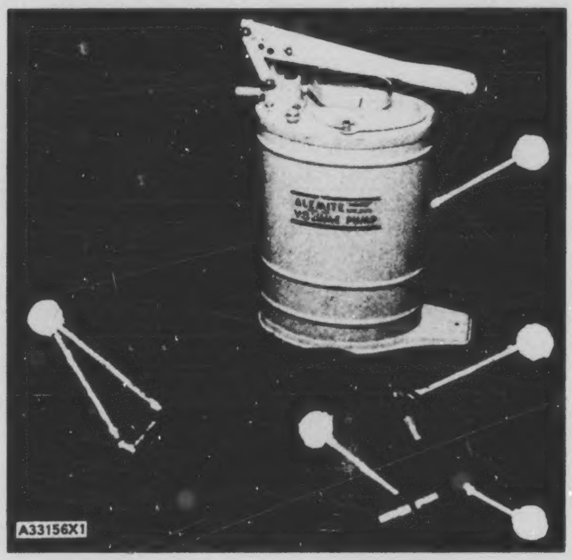
To reduce the nitrogen pressure in the cylinders the vehicle must be empty and on ground level. A charging chuck is used to release the nitrogen. Both front cylinders should be bled at the same time, as should both the rear.

Bleeding Procedures

1. Before bleeding the cylinders support the vehicle's weight with a jack or with blocks.
2. Install nitrogen charging chucks on the nitrogen valves of both front or rear cylinders and open the chucks to unseat the nitrogen valve.
3. Using a jack lower the vehicle's weight onto the cylinders until the rods are completely retracted and all the nitrogen exhausted.

Checking Cylinder Oil Level

Once the nitrogen has been bled from the cylinders, the oil can be checked. The checking is done by pumping oil into the cylinder through the nitrogen charging valve using equipment such as shown in Figure 6-286. When oil flows from a vent, the cylinder has the right amount of oil. (See the service manual for specific procedures.) Note that the oil must be checked in both the front or both the rear cylinders because the cylinders must be simultaneously recharged with nitrogen.

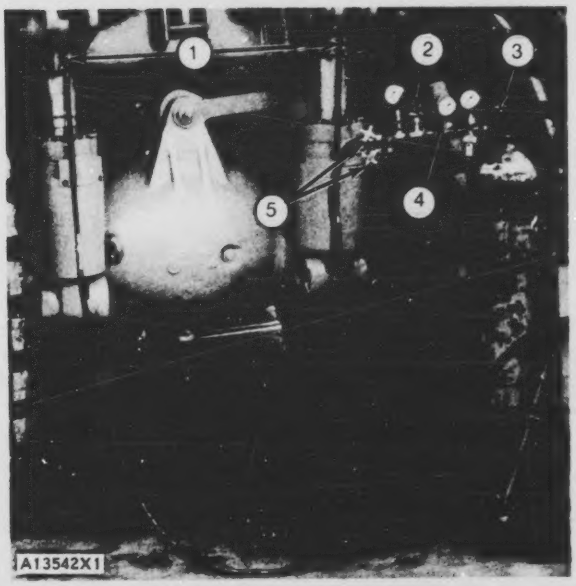


(6-286) OIL CHARGING EQUIPMENT

Courtesy of Caterpillar Tractor Co.

Charging The Cylinders With Nitrogen

Warning: Dry nitrogen is the only gas approved for use in suspension cylinders. Accidental charging a cylinder with oxygen will cause an explosion. This danger can be eliminated by only using nitrogen cylinders that have the correct connections. Never use an adapter to connect a nitrogen charging apparatus to a valve outlet that has been used interchangeably on nitrogen, oxygen, or other gas cylinders. Do not rely on color coding or other methods of identification to distinguish between nitrogen and oxygen cylinders. Be absolutely certain the tank contains dry nitrogen.



TYPICAL NITROGEN CHARGING ARRANGEMENT

1—Charging chucks (two). 2—Shutoff valve. 3—Nitrogen tank valve. 4—Pressure gauge. 5—Individual cut-off valves.

(6-287)

Courtesy of Caterpillar Tractor Co.

Charging procedures for both front and rear cylinders are the same. Setting the pressure at about 500 P.S.I. (35.15/ kg/cm²), the cylinders are charged with nitrogen until the piston rods are extended to the exact length specified in the manual.

Charging Procedures (Refer to Figure 6-287)

Warning: For personal safety it is very important that valves be opened or closed in the correct order.

1. Close the charging chucks (1).
2. Close shut-off valve (2).
3. Connect the nitrogen charging equipment.
4. Open the charging chucks (1).
5. Open the nitrogen tank valve (3) and adjust the valve until the gauge reads approximately 500 P.S.I. (35.15 kg/cm²).
6. Open the individual cut-off valves (5) and open the shut-off valve (2). Charge the cylinders until the proper extension is reached.
7. To stop the charge close:
   (a) the shut-off valve (2)
   (b) the nitrogen tank valve (3)
   (c) the charging chucks (1)
8. Note that step 7 must be followed each time the rod extension is checked while charging.
9. After performing step 7, the equipment can be disconnected.
10. Recheck the rod extensions after the vehicle has operated a few cycles. Increase the nitrogen pressure, if necessary.

REMOVAL AND INSTALLATION

Front Suspension

The basic procedures for removing front suspension cylinders are:

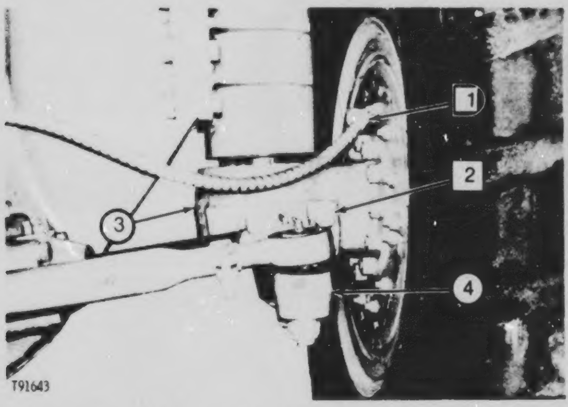
1. Bleed the cylinder, as previously described. The weight of the vehicle is held by blocks.
2. Disconnect the brake lines (Figure 6-288) and steering arm (if applicable).
3. Disconnect the cylinder piston or rod from the spindle. This step may involve special spindle-removing tools.

4. Roll or lift out the wheel assembly.

   Caution: On vehicles with large tires the wheel assembly is very heavy and will require proper lifting equipment.

5. Disconnect the cylinder from the frame.

   Caution: Suspension cylinders can weigh half a ton. Proper lifting equipment is needed to remove them.

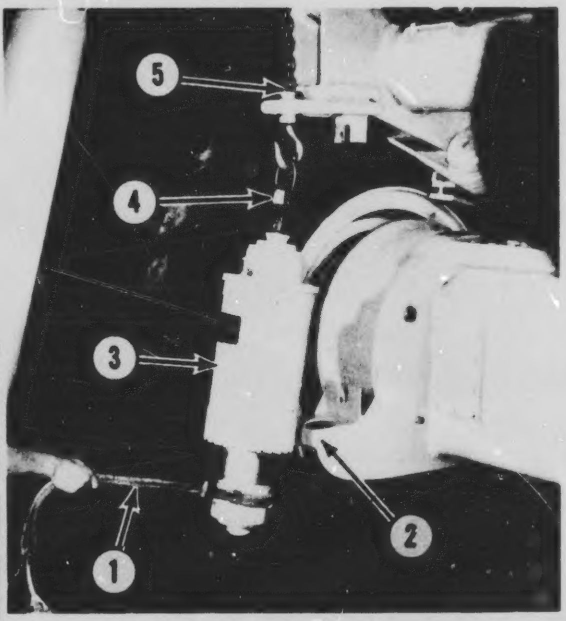


PREPARING TO REMOVE WHEEL AND SPINDLE
1 —Wheel brake hydraulic line. 2 —Bolts (four).
3 —Spindle. 4—Steering arm.
(6-288)
Courtesy of Caterpillar Tractor

6. The cylinder is installed in the reverse order.

Rear Cylinder Removal

Removing rear suspension cylinders, unlike front cylinders, does not require removing the wheels. The cylinder is bled of nitrogen and the vehicle is blocked. The cylinder is then removed from its two mounts and lifted out by a hoist. Note that on some off-highway haulage trucks, the dump body has to be removed before you can get the cylinder out because the hoist will not clear the rear portion of the body. Figure 6-289 shows a rear suspension cylinder being lifted out of a large truck (the dump body is removed). Refer to the service manual for specific cylinder removal procedures.



LOWERING SUSPENSION CYLINDER
1—Rope sling. 2—Mounting flange.
3—Suspension cylinder. 4—Lifting eye.
5—Chain hoist.
(6-289)
Courtesy of Wabco Construction and Mining Equipment

QUESTIONS — SPRING SUSPENSION MAINTENANCE AND REPAIR

1. The single most important suspension safety check for on-highway vehicles is to:
   (a) make sure the windshield is clean.
   (b) check for broken springs.
   (c) make sure all the lights work.
   (d) check tire condition and pressures.
2. What is an obvious sign of loose wheel nuts?
3. To check the piston extension on vehicles equipped with hydro-air suspension, the vehicle should be:
   (a) at operating temperature, loaded, and on level surface.
   (b) at operating temperature, loaded, and on any surface.
   (c) cold, unloaded, and on a level surface.
   (d) at operating temperature, unloaded, and on level surface.
4. Is there a difference between the recommended frequency of service on an off-highway vehicle and an on-highway vehicle? Briefly support your answer.
5. List the problems that loose U-bolts can cause.
6. When tightening U-bolts, it is recommended that the vehicle be:
   (a) loaded.
   (b) unloaded.
   (c) either loaded or unloaded; it doesn't matter.
   (d) on a level surface.
7. Briefly explain why it is recommended to cut a frame side rail at a 45 degree angle.
8. Why should a non-heat-treated frame not be welded in the corners and on the edges?
9. True or False. Heating a frame to straighten it is an acceptable practice if done carefully.
10. What are three ways that heat-treated frames are identified?
11. What is the recommended practice to stop further spreading of a crack on a non-heat-treated frame?
12. Why are plug welds recommended over edge welds for reinforcements on heat-treated frames?
13. True or False. Bent, cracked or damaged aluminum frame rails should not be straightened or repaired: they should be replaced.
14. When replacing bushings in the ends of equalizer beams, why is it not recommended to remove them with a torch?
15. What are the two main causes of leaf spring failure?
16. What four measurements are taken to check bogie alignment?
17. True or False. If one spring is replaced it is recommended that the other one be replaced as well.
18. What rule must be followed when removing and installing upper torque rods? Why?
19. Why is universal misalignment not usually a problem on single axle trucks?
20. What procedure **must** be followed before checking the oil level in a hydro-air suspension cylinder?
21. List the steps to bleed the gas charge on a pair of hydro-air suspension cylinders.
22. True or False. Since the oil level in the suspension cylinder cannot be checked visually, oil is pumped into the cylinder until it flows freely from a vent hole.
23. When recharging hydro-air suspension cylinders, the correct procedure is to:
   (a) charge only one at a time.
   (b) charge them as a pair, both front or both rear.
   (c) charge one front and one rear on the same side.
   (d) either of the above is acceptable.

ANSWERS — WHEEL MACHINE SUSPENSION

1. Rigid suspension: good stability, e.g., wheel loader, skidder, grader.

   Spring suspension: smooth ride, e.g., highway trucks.

2. A bolster allows the axle housing to oscillate giving the machine maximum ground contact when it is working in rough terrain.

3. On a skidder, the long section of the frame is forward and the short section to the rear because the engine and transmission are forward. Conversely, on a loader the short section is forward and the long section at the back.

4. The drive tandem housings oscillate parallel with the frame and the front axle pivots in the middle.

5. . . . siderails . . . cross members.

6. (b) channel, box and I-beam.

7. Spring

   Rubber

   Hydro-air

   Air

8. (c) rate

9. The constant rate spring has an eye on each end of the main leaf and therefore its working length remains the same.

   The progressive rate spring has only one eye on the main leaf, and a cam bracket on the rear. As the spring deflects, the point of contact moves toward the center, shortening the working length of the spring and making it stiffer.

10. A progressive rate spring provides a softer ride when the vehicle is unloaded and a stiffer spring when the vehicle is loaded.

11. (d) a greater number of axles, springs and tires.

12. (b) lowers the center of gravity for better stability.

13. Torque leaves.

14. Hendrickson equalizer beam suspension is mounted below the axles. Rockwell suspension, on the other hand, has the outer ends of the springs resting on top of the axles. The centers of the springs are attached to spring saddles which mount and oscillate on a dead axle called a trunnion shaft.

15. (c) Rockwell suspension.

16. Four drive pins encased in rubber bushings.

17. The front suspension units:

    1. Support the vehicle.
    2. Provide a steering axis to which the front wheel is attached.

18. (a) nitrogen.

19. Air suspension gives a soft ride. It is used on buses, furniture vans and on some highway trucks.

20. Leveling valves:

    — automatically control the air pressure required by the load.

    — maintain the frame at a constant height.

21. . . . anchor structure.

ANSWERS — RIGID SUSPENSION MAINTENANCE AND REPAIR

1. Install the steering safety bar.
2. Cleaning enables you to see problems in their early stages.
3. Bolster pins, articulation pins, front axle pins.
4. 1. Block the front wheels and support the frame so it will not tip.
   2. Support the counter weighted end with a fork lift or similar lifting device.
   3. Neutralize the hydraulic pressure before disconnecting the hydraulic lines.
5. — mounting brackets and pads.
   — worn bolt holes.
   — frame cracks.
   — weld cracks.
   — center pins and bushings on articulated machines.
   — bolster pins and bushings.
6. Oscillation bearing, thrust rings, O-rings.

ANSWERS — SPRING SUSPENSION MAINTENANCE AND REPAIR

1. (d) check tire conditions and pressures.

2. Rust streaks from stud holes.

3. (d) at operating temperature, unloaded, and on level surface.

4. Yes. Off-highway vehicles require more frequent service because their work and operating conditions are more severe.

5. — Spring leaf breakage.
   — Axle misalignment.
   — Hard steering.
   — Abnormal tire wear.

6. (a) loaded.

7. A 45 degree angle distributes the cut and weld over a greater area than a cut made at right angles.

8. Welding the frame corners and edges encourages development of new cracks.

9. False.

10. — stencil marking.
    — "Brinell" marks.
    — "H" stamped on the upper face of the rail near the rail end.

11. Drill a hole at the starting point of the crack.

12. They provide a reduced heat affected zone, increased flexibility and reduced stress concentrations.

13. True.

14. The heat from the torch will weaken the heat-treated beams.

15. — Loose U-bolts.
    — Metal fatigue.

16. Measure from the straight edge to the:
    1. connecting tube centers.
    2. front-rear axle centers
    3. back-rear axle centers.

    Also measure (4) the distances between the axle centers.

17. True.

18. The adjustments or adjusting shims for the torque rods must not be changed. If the adjustment is changed the universal joint flanges on tandem axle vehicles would be thrown out of alignment.

19. Because (1) spring saddles are solidly fixed to the housing and (2) the front of the rear spring is attached to the frame bracket by shackle pins.

20. All nitrogen pressure must be bled from the cylinder.

21. (a) Support the vehicle weight with a jack.

    (b) Install charging chucks on the nitrogen valves of two cylinders (front or back) open the chucks.

    (c) Using a jack, lower the vehicle until the rods are completely retracted and all the nitrogen is exhausted.

22. True.

23. (b) change them as a pair, both front or both rear.

TASKS — WHEEL MACHINE SUSPENSION

RIGID SUSPENSION (GRADERS AND LOADERS)

Daily, Routine Maintenance Checks

On a grader or loader:

1. Check for and tighten any loose suspension mountings.
2. Check the frame and mounting brackets and plates for cracks or other damage. Report any service repair needed.

Service Repair

On a grader or loader, using the correct tools, lifting equipment and procedures outlined in the service manual:

1. Jack and securely block the machine. (On articulated machines insert the steering safety rod.)
2. Remove from their mountings the drive housings on a loader or the tandem housings on a grader.
3. Inspect the mounting brackets for cracks or damage and make any necessary repairs.
4. Reinstall the housings.

SPRING SUSPENSION (ON-HIGHWAY AND OFF-HIGHWAY TRUCKS)

Daily, Routine Maintenance Checks

1. Check hangers, U-bolts, springs, spring saddles, walking beam bushings, torque arm bushings, shackle pins and bushings (if equipped) for looseness, wear, cracks, or other damage. Make any minor repairs: report any major service repair needed.

Scheduled Maintenance Checks

1. Clean suspension parts and check the frame, cross members and suspension mounts for cracks, loose rivets or other damage. Make any minor repairs; report any major service repair needed.
2. Consult the service manual on suspension alignment. Park the truck on a level floor area, and using a tape measure, straightedge and string line, check the alignment of the suspension. If the suspension is misaligned, adjust it with the assistance of a journeyperson.
3. If a truck with hydro-air suspension is available, check the cylinders for any signs of leakage or damage and retorque the mounting bolts. (See the service manual.) With the assistance of a journeyperson check for correct piston extension and pressure. Adjust if needed.

Service Repair

1. Using the correct jacking and blocking procedures, raise a truck to a height that will allow removal of the suspension unit. If the vehicle has hydro-air suspension, follow procedures for bleeding down the gas charge before removing the air suspension.
2. Remove the suspension unit.
3. Inspect the frame, cross members, and suspension mounts for wear, cracks, loose rivets and other damage. Make any minor repairs: report any major service repair needed.
4. Remove the wheels and disassemble the suspension unit by removing, for example:

   U-bolts, springs, spring saddles, walking beams, torque arms and shackle pins and bushings.
5. Inspect the suspension components for wear and damage. Write a parts list. Make any necessary repairs or replacements.
6. Reassemble the suspension unit including the wheels. Install the suspension unit.
7. Lower the truck. Check and adjust the alignment and lubricate where necessary. If the truck has hydro-air suspension, under the assistance of the journeyperson apply the gas charge to the specified pressure and suspension height.

BLOCK

6

Tires, Rims and Wheels

TIRES

INTRODUCTION

This unit does not try to make you a tire expert, but rather tries to give you a working knowledge of tires. A mechanic should know how tires are constructed and how they operate. He should also be able to recognize types of abnormal wear patterns and be able to point to the steering, suspension, or brake problem that is causing the wear. Note that although an attempt has been made to use the most common tire words, tire terminology is not standardized in the industry, so some of the words used here may be different than those of a given tire manufacturer.

Purpose Of Tires

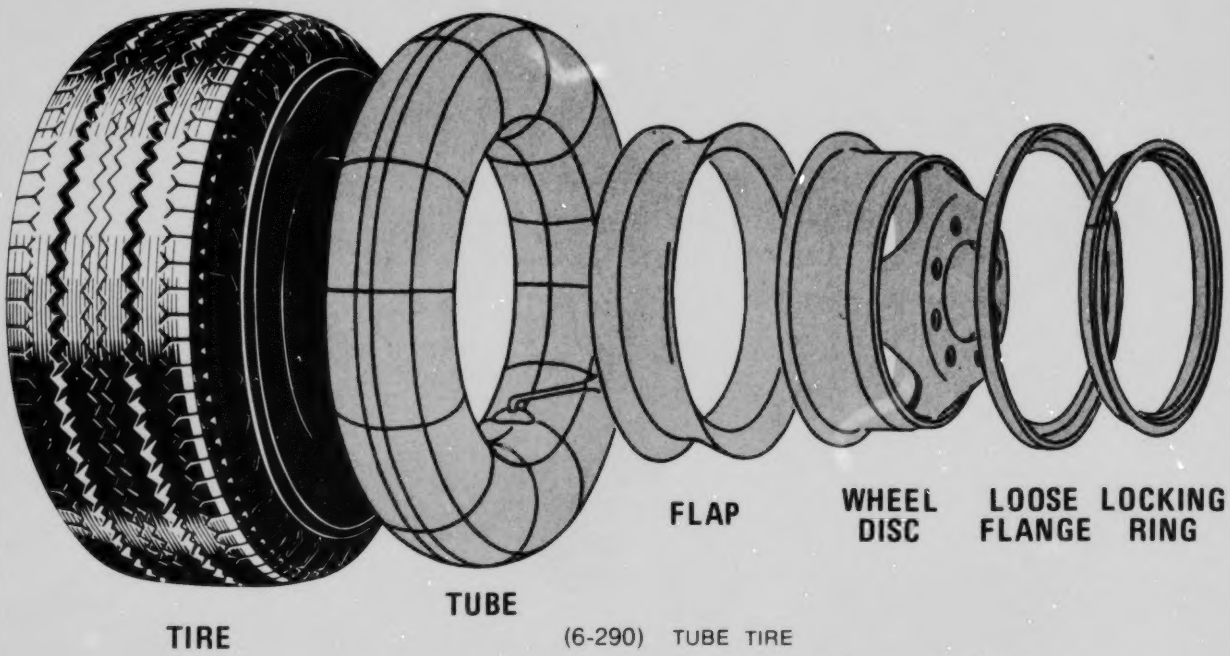
The general purpose of tires on wheel vehicles is similar to the purpose of tracks on a crawler machine. Tires must:

- — support the machine
- — give traction
- — provide flotation
- — absorb or cushion shocks
- — provide a replaceable wear surface

There are two general types of tires: over-the-road tires and off-the-road tires. Over-the-road tires are made for speeds over 48 km/h (30 mph) on highways. These tires flex quickly and generate a substantial amount of heat. Off-the-road tires are made for speeds under 48 km/h on rough off-highway surfaces. They are very durable so as to withstand the shocks of such obstacles as rocks and stumps. (Note that some tires will fall between these two types, having characteristics of both.) Service of over-the-road tires is usually done at tire shops, whereas many off-the-road tires are often serviced in the field.

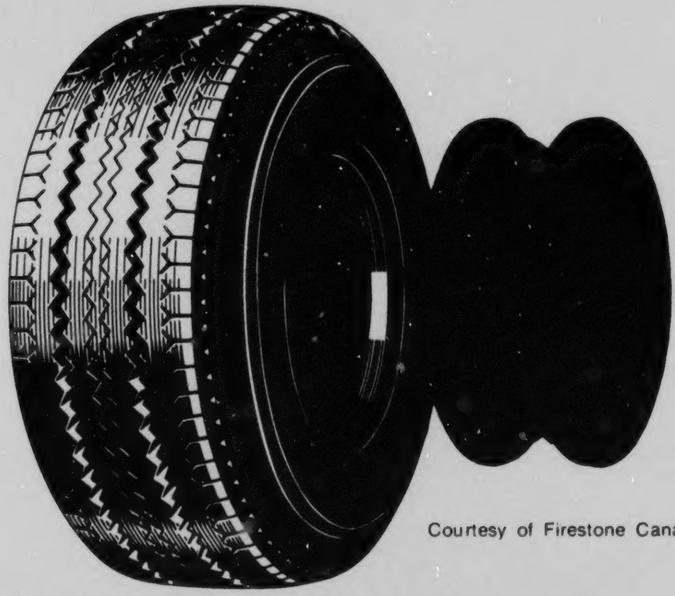
TIRE CONSTRUCTION

Tires either have inflatable inner tubes (Figure 6-290) or are tubeless (Figure 6-291). In tubeless tires, air is sealed between the rim and tire casing. Tire casings for both tube and tubeless tires are similarily constructed. Basic tire parts are illustrated in Figure 6-292 and are discussed below.



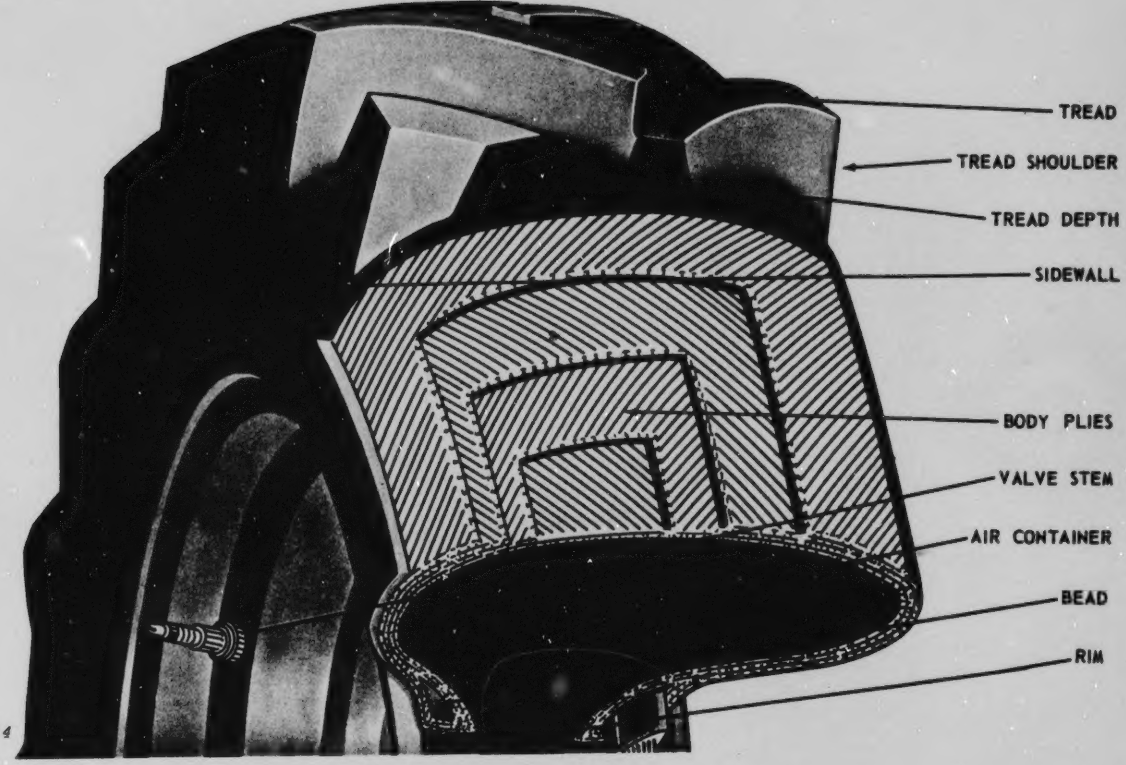
(6-290) TUBE TIRE

Courtesy of Firestone Canada Inc



Courtesy of Firestone Canada Inc.

(6-291) TUBELESS TIRE


TREAD
TREAD SHOULDER
TREAD DEPTH
SIDEWALL
BODY PLIES
VALVE STEM
AIR CONTAINER
BEAD
RIM
X2534

(6-292)

Courtesy of John Deere Ltd.

Bead

Tire beads are strong bundles of wire that anchor the tire (i.e., the plies) to the rim. They maintain the tire's shape, and its fit to the rim. Tires may have one or more bead stacks.

Body Plies

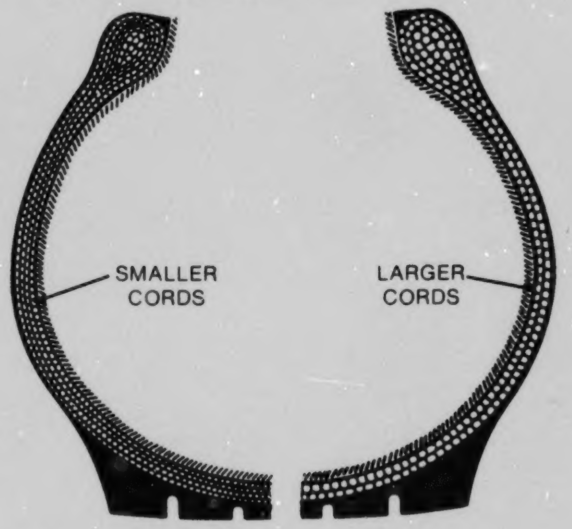
Plies are layers of rubber-cushioned cord or fabric that make up the body of the tire. The strength built into the plies retains the air pressure that supports the load and cushions the shocks. Each cord in each ply is completely surrounded by a resilient rubber compound, and each ply is insulated from the next by a layer of the same compound.

The cord material may be made of cotton, rayon, nylon, polyester, or other materials. Rayon and nylon have been the most popular, but recently more and more tire cords are being made with polyester.

Tires have different numbers of plies. Tires for automobiles, station wagons and light pick-up trucks have two, four or six plies. Tires for large highway trucks have from six to 14 plies and tires for large off-highway equipment can have up to 20, or more, plies.

Ply-Rating

Ply-rating indicates the strength of a tire, but does not necessarily tell the number of cord plies the tire has. For example, a tire with a four ply rating may only have two plies. The four ply rating means that the two plies have added strength and will carry the load of a tire that has four standard plies (Figure 6-293). All off-the-road tires are ply-rated. Automobile and truck tires used to have a ply-rating but are now identified by what is called a load range. Load range, discussed later, gives the range of the load a tire will carry at its maximum inflated pressure.



X2535

4-PLY TIRE

2-PLY TIRE FOUR PLY RATED

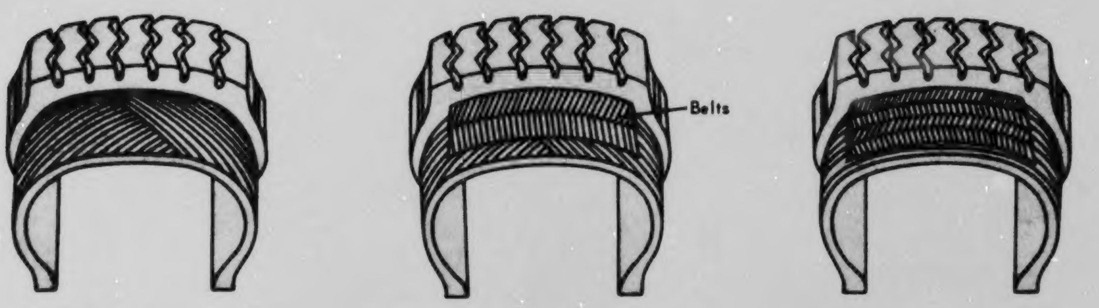
(6-293)

Courtesy of John Deere Ltd.

Types Of Ply Construction

Bias Ply

Standard tires have a bias ply construction. Bias means that the ply cords run from one tire bead to the other at an angle. Alternate plies run at diagonals to one another (Figure 6-294). Bias play construction gives rigidity to both the sidewall and the tread. Two disadvantages of bias ply are (1) the layers of ply tend to work against one another creating a heat which can be a problem at high speeds, and (2) bias ply tends to cause the tread to tighten or squeeze at the road surface increasing tire wear.



BIAS PLY BELTED BIAS PLY BELTED RADIAL PLY

X2536

(6-294)

Courtesy of John Deere Ltd.

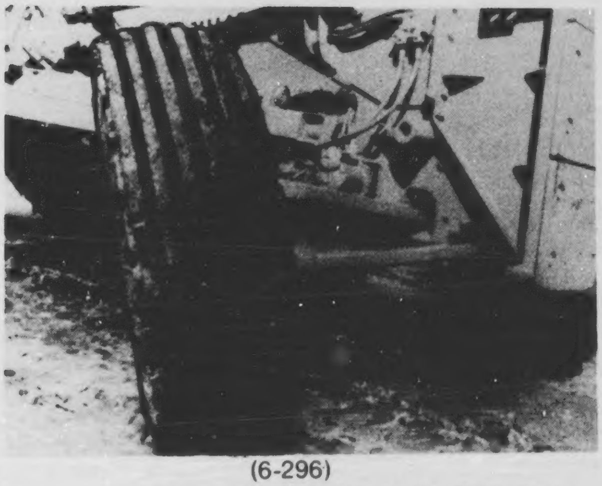
Belted-Bias Ply

Belts are added to a bias ply construction to make a belted-bias ply tire. The belts are composed of very low angle cords; they surround the tire body underneath the tread. This construction gives rigidity to both the sidewalls and the tread. The belts reduce tread motion during contact with the road and thus improve tread life.

Belted-Radial Ply

On a belted-radial ply tire the ply cords run across the body from bead to bead at almost a right angle. Fairly rigid belts composed of steel or fabric cords surround the tire body underneath the tread. As with belted-bias tires, the belts reduce tread motion during contact with the road, and thus improve tread life. Radial ply construction gives better support to the tread than the other two types of ply. Three advantages are claimed for radial tires:

1. They generate less heat when properly inflated.
2. A broader base of rubber contacts the road making the tire less likely to skid, especially at corners.
3. They wear better because they don't cause the tread to squeeze.



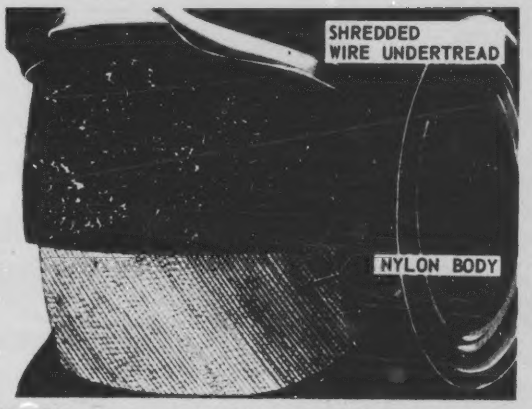
(6-296)

Courtesy of Caterpillar Tractor Co.

Both bias ply and radial ply tires are used on heavy duty equipment, but the trend is towards radial ply. Note that the type of ply construction of a tire is often marked on the tire: B for bias-belted; R for radial; and D for bias (diagonal).

Wire Reinforced Ply

Some big tires for earthmoving and other equipment, have a layer of wire between the tread and the body of the tire (Figure 6-295). This protective layer of wire keeps most cuts from penetrating the tire body. It also keeps tread cuts from enlarging and holds them closed so that sand and dirt will not enter and cause separation.



(6-295) WIRE-REINFORCED CONSTRUCTION OF HEAVY-DUTY TIRE

Courtesy of John Deere Ltd.

Sidewalls

Sidewalls are the rubber coverings on both sides of the body. They are made to flex and bend without cracking during both ordinary deflection and extreme sudden shock.

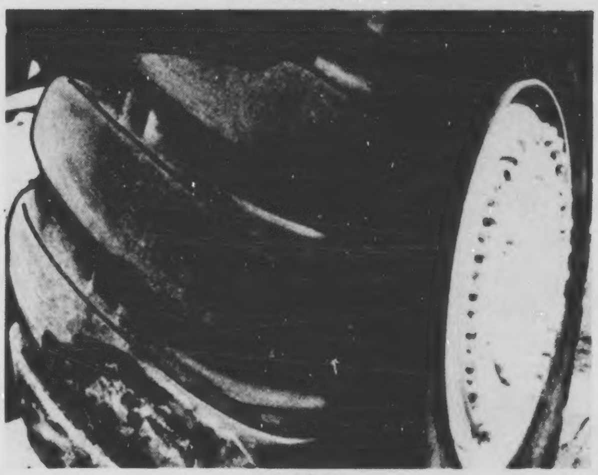
Tread

The tread is the part of the tire which contacts the road. It must provide traction, give long wear and resist cuts. Tire treads have many patterns and depths for different types of service. Examples of tread for off-the-road tires are given in Figure 6-296 and for over-the-road tires in Figure 6-297.

Ribbed tires are found mainly on scrapers and motor graders. The deep grooves resist any side thrust, and the heavy lugs on the sidewalls give added protection.

(6-296)
Courtesy of Caterpillar Tractor Co.

Traction tread tires are found on many scraper tractors and wheel dozers, and on the front and rear of some motor graders. The angled bars are designed to force mud and dirt out to achieve better traction. The wedge shape of the bars helps clean the tread when it is not in contact with the ground.



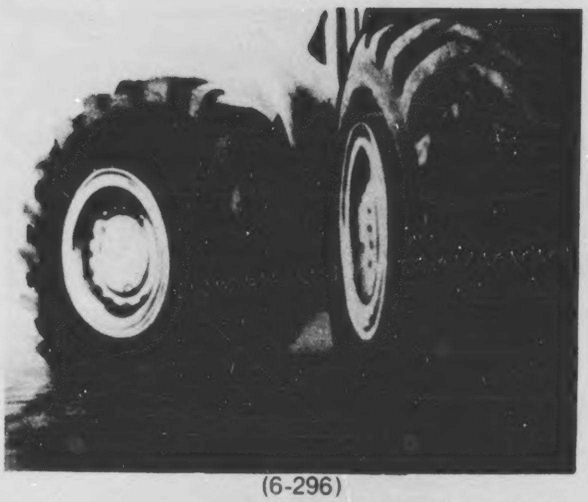
(6-296)
Courtesy of Caterpillar Tractor Co.

Rock tires are used on scrapers, wheel loaders and trucks working in rock quarries. The bars on these tires provide excellent resistance to cutting and bruising by rocks. The larger bars give increased tire-to-ground contact and much better weight distribution.

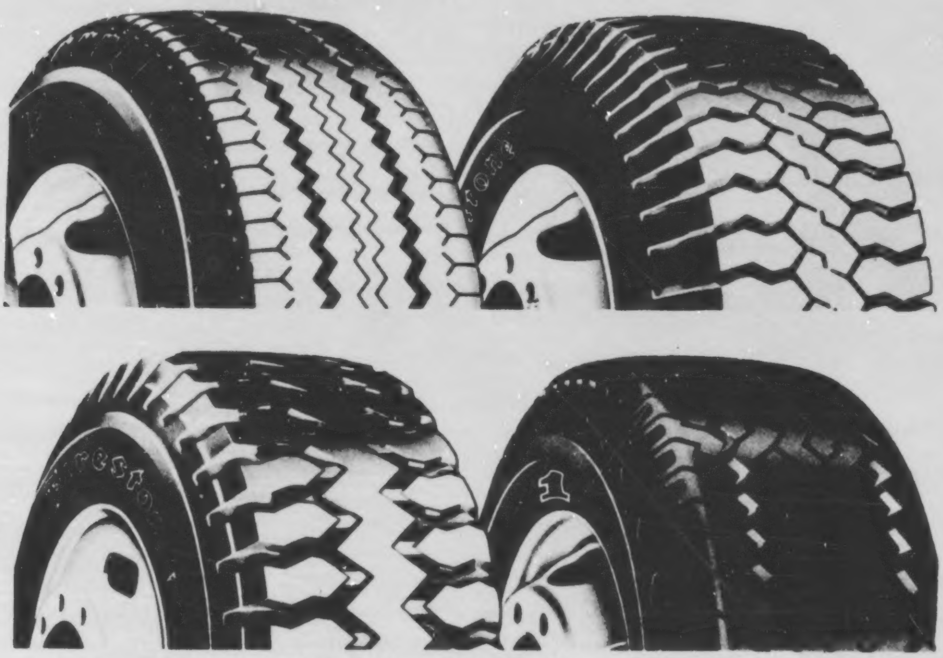
(6-296)
Courtesy of Caterpillar Tractor Co.

Flotation tires are used primarily on free rolling wheels or for general traction. They are a very wide tire and thus distribute the vehicle weight over a broad surface area. The lugs are placed close together to give a reasonably smooth ride.

V-treads are designed for traction in soft material. Graders and agricultural machinery use V-treads.



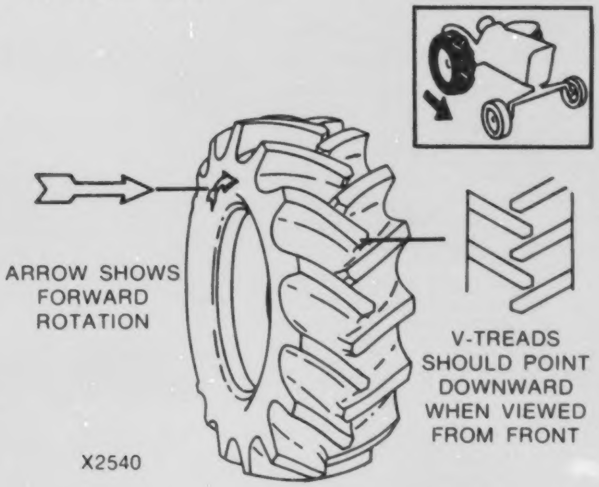
(6-296)
Courtesy of Caterpillar Tractor Co.



(6-297) OVER-THE-ROAD TIRE TREADS
Courtesy of Firestone Canada Inc

Tread Directional Arrows

Drive wheel tires on many machines must be mounted to rotate in a certain direction for best traction. For this reason, directional arrows are often stamped on the sidewall to show forward rotation (Figure 6-298). This is most important on V-tread tires where the V pattern must point downward when viewed from the front.


ARROW SHOWS FORWARD ROTATION
V-TREADS SHOULD POINT DOWNWARD WHEN VIEWED FROM FRONT
X2540

(6-298) DIRECTIONAL ARROWS ON TIRES
Courtesy of John Deere Ltd.

Tubes

The function of the inner tube in a tube tire is to retain air, inert gases, or liquid under pressure within the tire case. When inflated it is donut shaped and fits perfectly inside the tire casing. Tubes are made of the same type of rubber as the tire. A valve stem is vulcanized to a spot on the tube's inner circumference, providing a means of inflating and deflating the tire.

Flaps

On tube tires, flaps give puncture protection by shielding the tube from contact with the rim and tire beads.

Tubeless Inner Liners

Tubeless tires have a thin rubber liner that coats the inside of the tire from bead to bead. The liner, like an inner tube, retains the air. The rubber liner reduces the overall weight of the tire by eliminating tubes and flaps; it is also easier to maintain than an inner tube.

Rims

Rims are the part of the wheel that support the tire. Rims are discussed in more detail later in this section.

TIRE SIZE AND LOAD RANGE

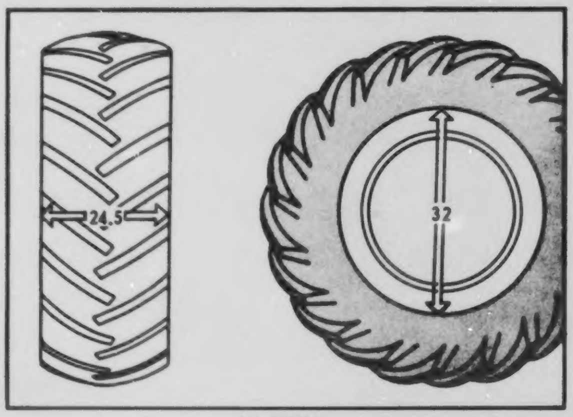
Tire Size

The size of a tire is indicated by:

- — the width of the tire
- — the tire's rim size.

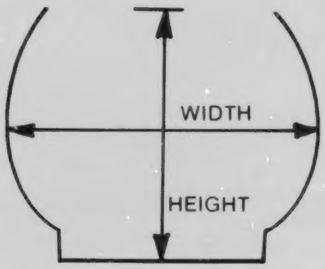
Figure 6-299 shows a typical size marking on the sidewall of an off-the-road tire. The 24.5 is the section width of the tire (in inches) when mounted on its recommended rim. The 32 gives the nominal diameter in inches of the rim (Figure 6-299). Note, if metric measurement is used, the figures will represent centimeters.

(6-299) NORMAL SIZING
Courtesy of John Deere Ltd.



(6-299)
Courtesy of John Deere Ltd.

Another system used by some manufacturers to show tire size is to give a figure on the sidewall that represents the ratio of the height to the width of the tire donut (Figure 6-300). The figure, 78, for example, means that the tire donut is 78 percent as high as it is wide (i.e., the donut width is about one quarter bigger than its height). Tires are available in four height-weight ratios: 83, 78, 70, and 60.



(6-300)

Load Range Of Tire

Load range, as stated earlier, is the load limit a tire can carry at its maximum pressure. Load range has replaced ply rating as a means of rating on-highway tires. Load range is indicated by a capital letter A, B, C, D, E, F, G and so on. Each letter stands for a certain load and inflation limit. For example, a load range of F means that the tire has a load limit of 1500 lbs. at 32 p.s.i. In the metric system kilograms (kg) are used instead of lbs. and kilopascals (kPa) in place of lbs. per square inch.

FACTORS IN SELECTING OFF-THE-ROAD TIRES

The type of tread, as stated earlier, is a factor in selecting tires to do a job. Two other factors are load size and machine speed, which together give the Ton-Mile-Per-Hour Rating (TMPH) that is used in choosing a tire of suitable size and strength. The TMPH for a large earthmover would be found in the following way (Courtesy of Caterpillar):

$$\frac{(\text{weight empty}) + (\text{weight loaded})}{2} = \text{Average Tire Load}$$

Obtain the weights in tons carried by the tires when the machine is empty, and then when it is loaded. These two weights should be totalled and divided by two. This figure is the **average tire load** in tons.

$$\frac{(\text{cycles per day}) \times (\text{miles per cycle})}{\text{number of working hours per day}} = \text{Average Speed}$$

An average speed is then obtained by multiplying the cycles per day (that is, the number of trips from the cut to the fill and return) by the distance travelled per cycle in miles to give the total miles travelled per day. The product is divided by the hours in a work day to obtain the **average speed.**

$$(\text{average speed}) \times (\text{average tire load}) = \text{T.M.P.H.}$$

The **average speed** is multiplied by the **average tire load** and the product is the **Ton-Mile-Per-Hour** rating.

RIMS AND WHEELS

Rims

Tires are mounted on rims. Rims may be part of or separate from the wheel; those separate from the wheel are called demountable rims. Most automobiles and heavy duty vehicle rims and wheels are made of steel. In the past few years, however, other metals such as magnesium (automobiles) and aluminum (automobiles and on-highway heavy duty trucks) are being used for rims as well. Rims and wheels differ in size, shape, method of mounting and in whether they are made for tube or tubeless tires. Note that tires and rims must be matched, i.e., rims must be used with the correct size and type of tire. Many tire failures have been caused by mismatching tires and rims.

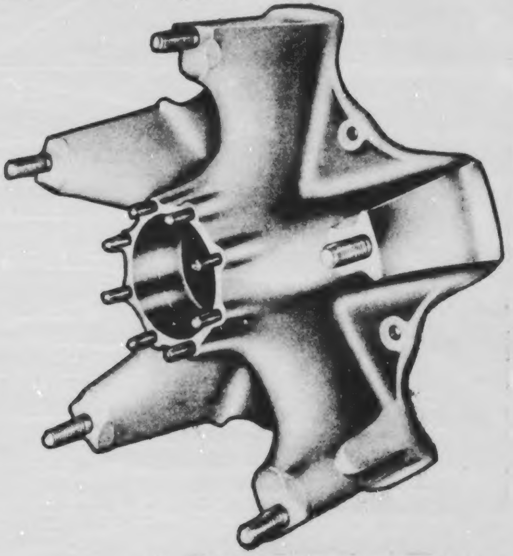
TYPES OF HEAVY DUTY WHEELS AND RIMS

There are three main types of heavy duty wheel-rim combinations.

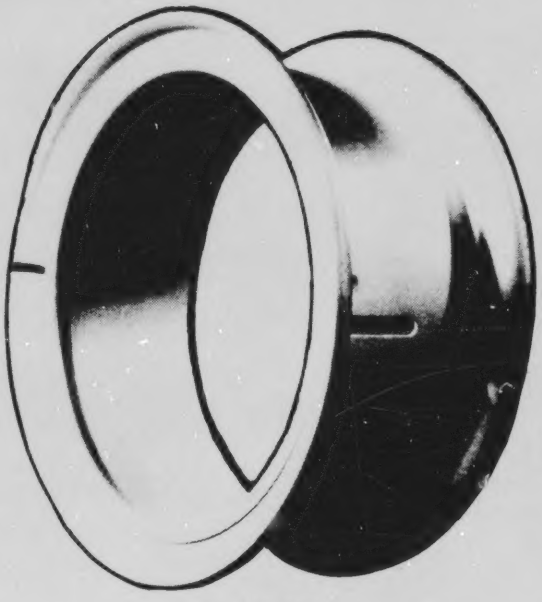
1. Cast Spoke Wheel with Demountable Rim — wheel and rim separate.
2. Disc Wheel and Rim — wheel and rim combined.
3. Split Disc Wheel and Rim — similar to disc wheels except that the wheel and rim is made in two halves. The two halves are joined together near the center by bolts located just outside the center mounting flange holes. These wheels are not dished like disc wheels and are used only for single wheel applications.

Cast Spoke Wheels and Demountable Rims

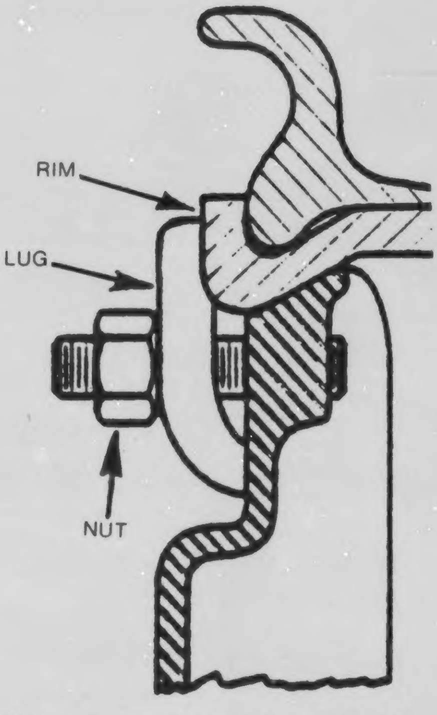
Figure 6-301 shows a typical cast spoke wheel and demountable rim. Note that the wheel and hub are integral parts. The rim slides over the wheel and is retained by clamps (lugs) and nuts. The lugs fit over hub studs and grip the outside edge of the outer lip of the rim as shown in the figure.



(6-301) Courtesy of Dayton-Walther



(6-301)

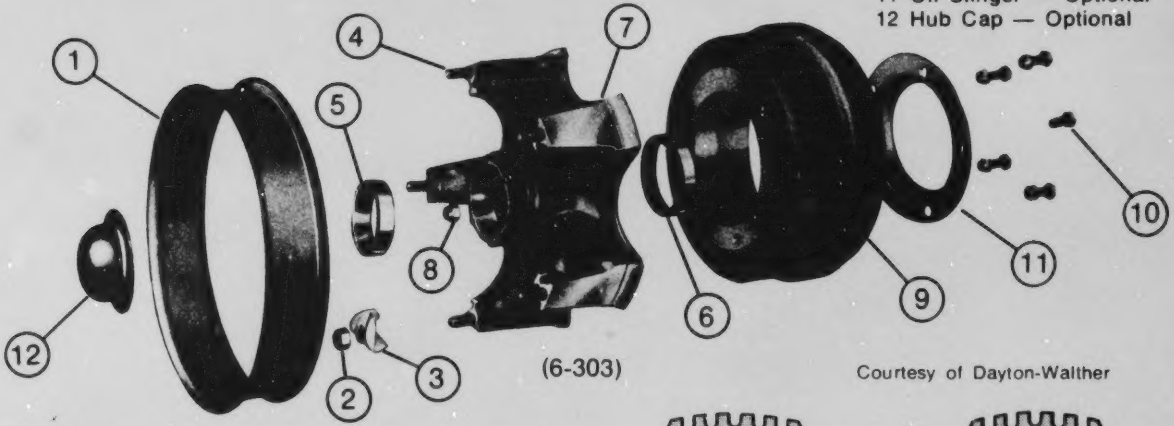


(6-302) TYPICAL FRONT MOUNTING ON CAST WHEELS

Courtesy of Kenworth Truck Co.

Figure 6-303 shows a complete spoke wheel assembly including the brake drum. Note how the wheel is attached to the brake drum. When a tire on a spoke wheel is changed only the rim and tire are removed (Figure 6-303).

1 Rim Spacer
2 Rim Nut
3 Rim Clamp
4 Rim Stud
5 Bearing Cup — Outer
6 Bearing Cup — Inner
7 Wheel
8 Brake Drum Nut
9 Brake Drum
10 Brake Drum Bolt
11 Oil Slinger — Optional
12 Hub Cap — Optional

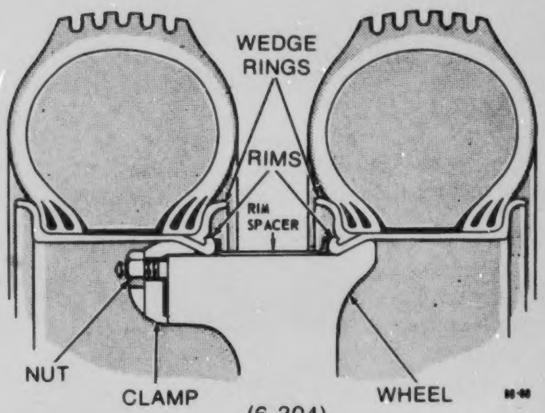


(6-303)

Courtesy of Dayton-Walther

Dual tires are also mounted on cast spoke wheels; two rims and their tires are mounted on a single wheel (Figure 6-304). The rim mounting surface on the dual wheel is wider to accommodate the two rims. Lugs (Figure 6-305) grip on the inner edge of the outside rim and hold both rims to the wheel. The rims are placed on the wheel so that the valve stems are 180 degrees apart and don't interfere with one another. The driving lugs (Figure 6-306) on the rims are located next to a spoke for both curb and roadside installations; this prevents rims from slipping on the wheel and possibly shearing the valve stems.

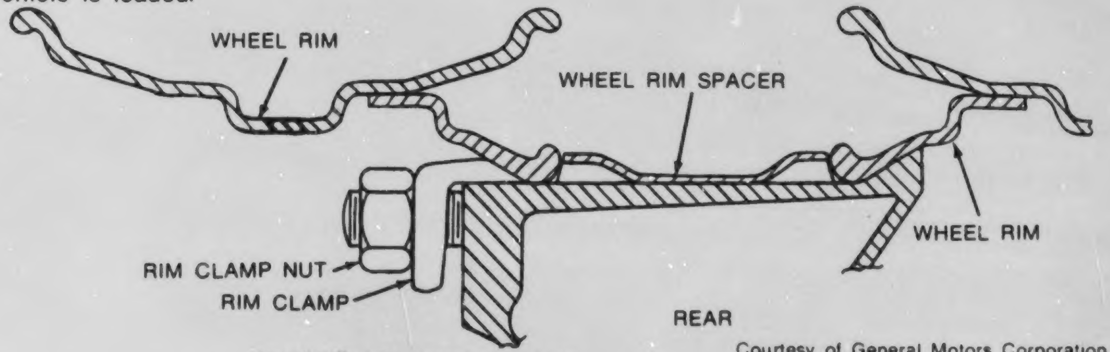
Note in Figures 6-304 and 6-305 that (1) both rims overhang the wheel by most of their width and (2), a rim spacer is placed over the wheel between the two rims to prevent the tires interfering with one another when the vehicle is loaded.



(6-304)

TYPICAL DUAL MOUNTING ON SPOKE WHEEL

Courtesy of Mack Truck Limited



(6-305) CAST WHEEL MOUNT

Courtesy of General Motors Corporation

Proper Positioning of Rim Drivers

Curb side trailer and front wheels — Rotate rims clockwise until rim driver contacts wheel bevel/clamp.
Road side trailer and front wheels — Rotate rims counterclockwise until rim driver contacts wheel bevel/clamp.

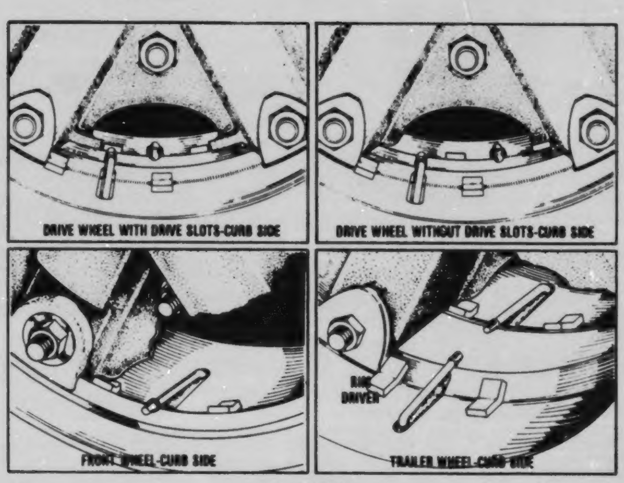
Curb side drive wheels — Rotate outer rim clockwise until rim driver contacts rim clamp. If wheel does not have slots, rotate inner rim counterclockwise until rim driver contacts wheel bevel.

Road side drive wheels — Rotate outer rim counterclockwise until rim driver contacts rim clamp. If wheel does not have drive slots, rotate inner rim clockwise until rim driver contacts wheel bevel.

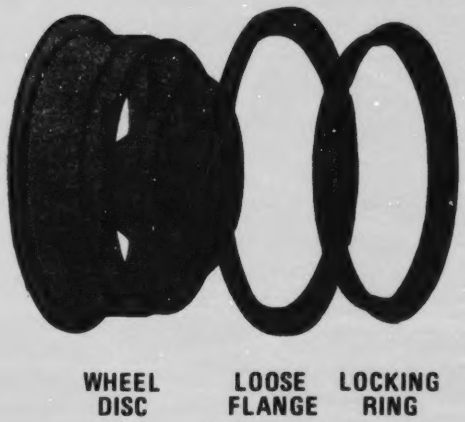
Disc Wheel and Rim

A typical dropped-center or dished disc wheel and rim is shown in Figure 6-307. The disc wheel and rim, unlike the cast spoke wheel and demountable rim, is made with the wheel and rim joined together. This particular one is a ten stud wheel for a tube tire. The number of stud holes vary with size and load capacity of the rim.

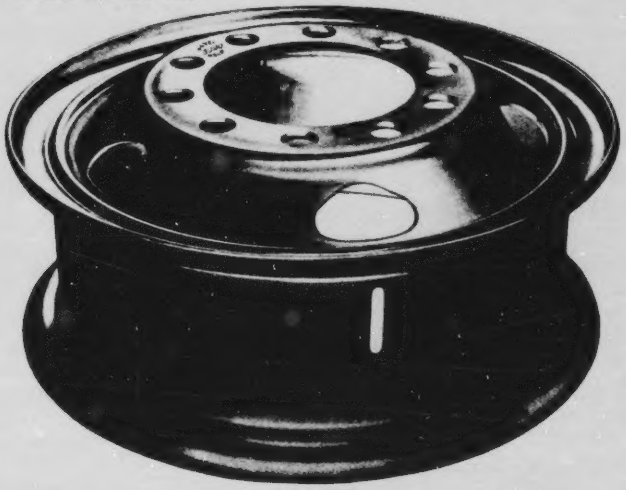
To mount a tube tire on a disc rim, the tire and tube are slid onto the rim, held in place by the flange and locking rim (Figure 6-308), then inflated. To mount a tubeless tire on a disc rim (Figure 6-309), the beads of the tire must be pryed over the rim edge as there is no locking ring arrangement like on the tube rim. The tire is then inflated through a special valve stem fixed in the rim.


DRIVE WHEEL WITH DRIVE SLOTS-CURB SIDE
DRIVE WHEEL WITHOUT DRIVE SLOTS-CURB SIDE
FRONT WHEEL-CURB SIDE
RIM DRIVER
TRAILER WHEEL-CURB SIDE

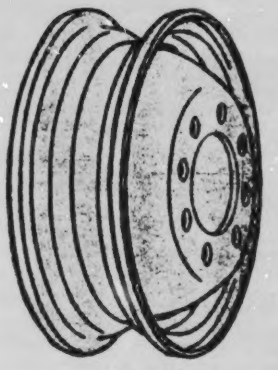
(6-306)


WHEEL DISC
LOOSE FLANGE
LOCKING RING

(6-308)
Courtesy of Firestone Canada Inc



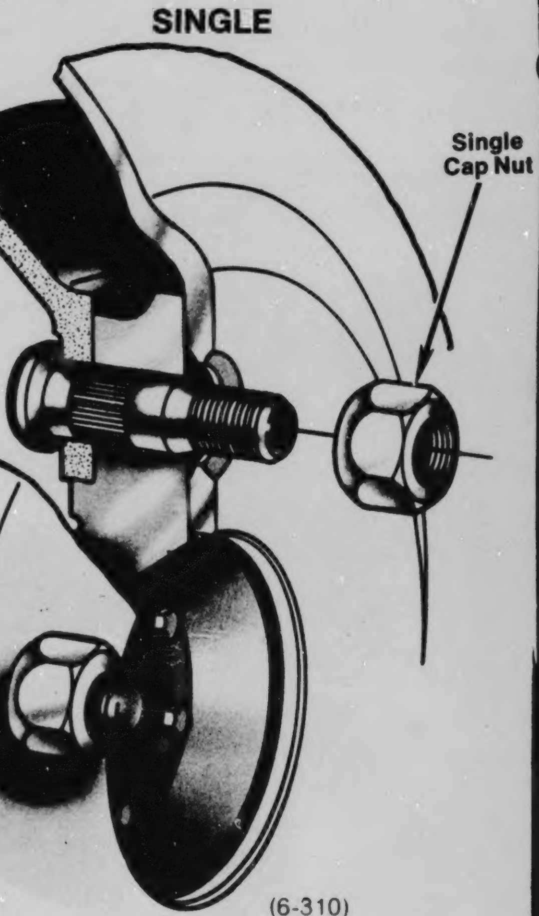
(6-307)
Courtesy of Budd Company



(6-309)
Courtesy of Firestone Canada Inc.

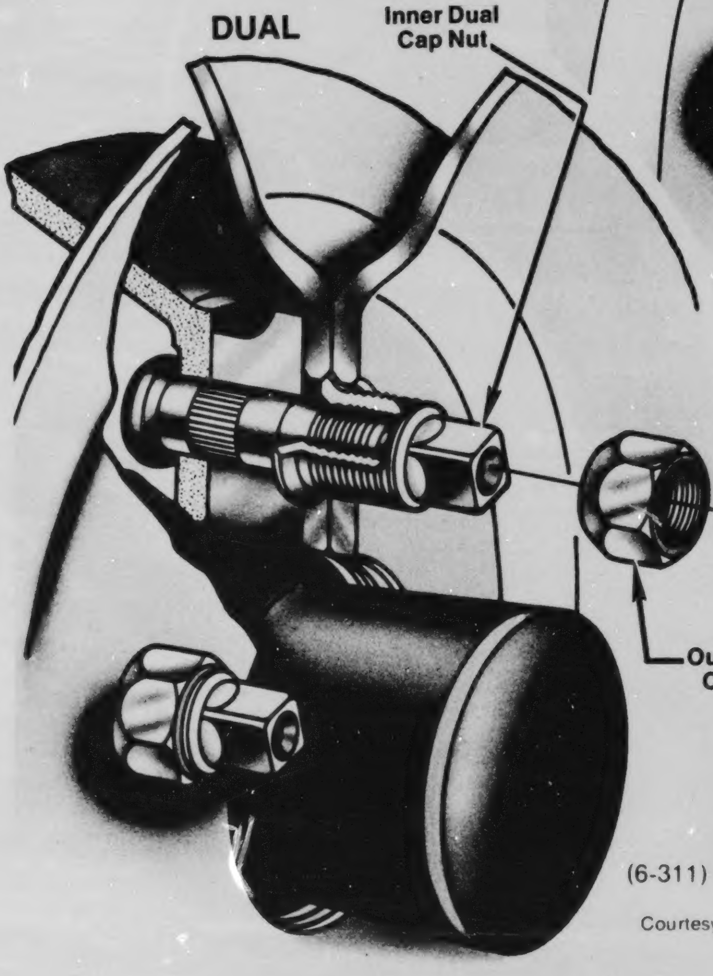
Disc Wheel Mounting

Disc wheels can be either single or dual mounted (Figures 6-310, 6-311). Several nut arrangements are available to hold the wheel to the hub, but the most common is the ball seat nuts, generally referred to in the trade as Budd nuts. (Budd manufacturers ball seat nuts.)


SINGLE
Single Cap Nut

(6-310)

Courtesy of Budd Company

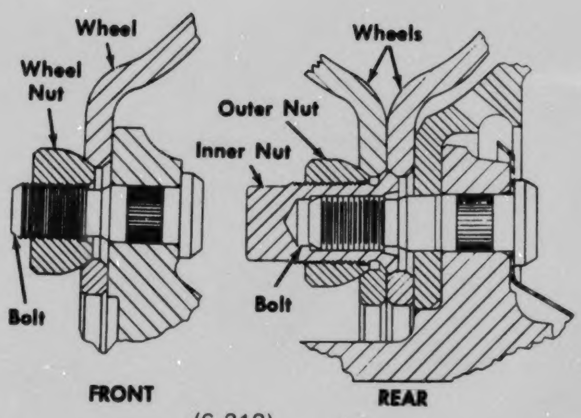

DUAL
Inner Dual Cap Nut
Outer Dual Cap Nut

(6-311)

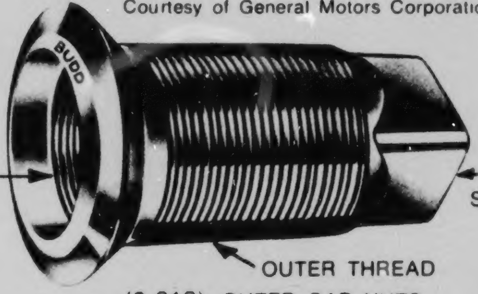
Courtesy of Budd Company

For single front-wheel mounting single nuts are used as shown in Figure 6-312. The wheel is placed over the hub studs, with the dished surface of the rim facing outwards. The nuts are then threaded on to the studs and tightened to secure the wheel.

For dual, rear-wheel mounting an inner and outer cap nut arrangement is used (Figure 6-312). The inner wheel with the dished part facing outwards, is placed over the hub studs, and the inner cap nuts (Figure 6-313) are threaded to the hub studs, then tightened to secure the wheel. The outer wheel is then placed over the inner cap nuts with the dish of the rim facing the inner wheel. The outer cap nuts (Figure 6-313) are tightened to the outer threads of the inner cap nuts, securing the outer wheel in place. The inner-outer nut arrangement (Figure 6-314) permits both wheels to be mounted to the same hub stud and allows the outer wheel to be removed without disturbing the inner one.


Wheel
Wheel Nut
Bolt
Wheels
Outer Nut
Inner Nut
Bolt
FRONT
REAR

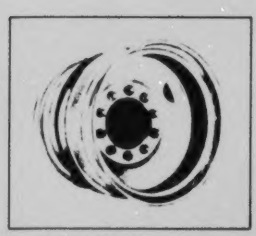
(6-312)
Courtesy of General Motors Corporation


BUDD
INNER THREAD
WRENCH SURFACES
OUTER THREAD

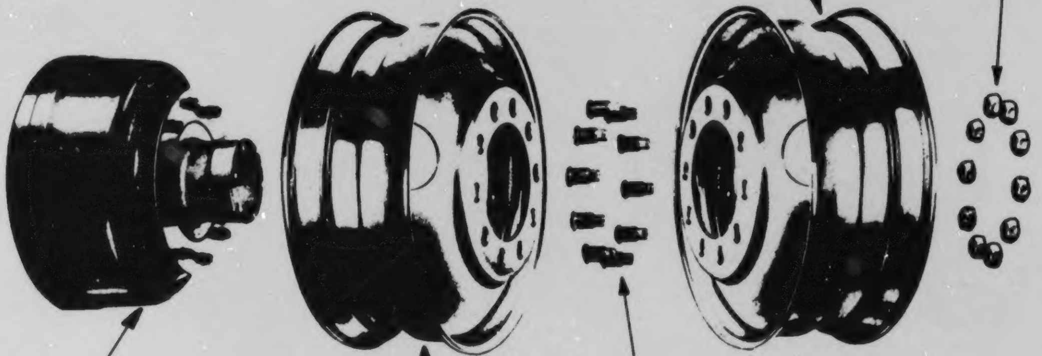
(6-313) OUTER CAP NUTS
Courtesy of Budd Company

(6-313) OUTER CAP NUTS
Courtesy of Budd Company

The Budd Mounting is a fixed rim (demountable-at-the-hub) wheel. This type assembly provides for positive torque transfer through the mating surfaces which are held in compression with studs and cap nuts. This is the simplest, strongest and most effective mounting available.



Assembled mounting


OUTER DUAL WHEEL
OUTER CAP NUT
HUB, DRUM AND STUD ASSEMBLY
INNER DUAL WHEEL
INNER CAP NUTS

Courtesy of Budd Company

(6-314)

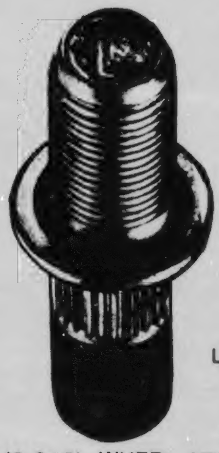
Left and Right Hand Threads On Studs and Nuts

The retaining nuts and corresponding studs for disc rims have the usual right-hand thread for the right-side of the vehicle, but use left-hand thread for the left-side. Markings on the end of the stud will easily identify left (L) or right (R) threads (Figures 6-315, 6-316). The nuts are also marked. Inner cap nuts are marked on their square end and the outer nuts on top (Figure 6-315). Another way of identifying left-hand threaded nuts is by slight cut marks at the corners of the nuts (Figure 6-315).

Split Disc Wheel and Rim

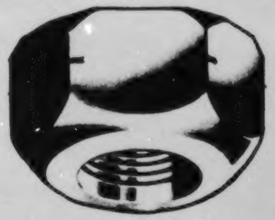
Special wheels having a two piece split rim construction are made for vehicles such as fork lifts and skidders. These wheels have a double set of nuts: one set holds the wheel on the hub while the other set holds the two wheel halves together. Caution must be taken when removing a split rim wheel. If the nuts that hold the wheel together are mistaken for the hub nuts, and are taken off first, you could be seriously injured by the rim flying apart. If ever in doubt as to which nuts hold the wheel halves together and which hold the wheel to the hub, deflate the tire before removing any of the nuts. This will eliminate any danger.

There is no standard method of marking split rim nuts and hub nuts. On some machines both sets of nuts are the same, and the service manual has to be consulted to find out which is which. Other machines identify the sets. One method is to insert a cotter pin through the outer end of the rim half bolts. Another is to make the two sets of bolts a different size, as is shown in Figure 6-317.



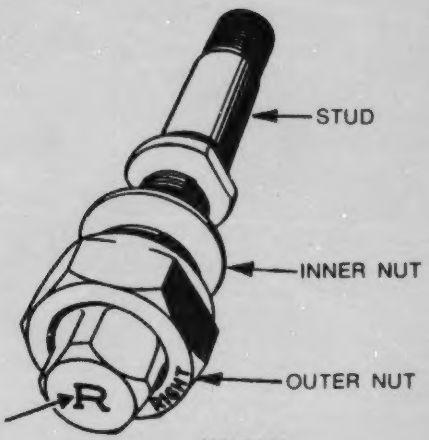
(6-315) WHEEL STUD

SINGLE WHEEL CAP NUTS



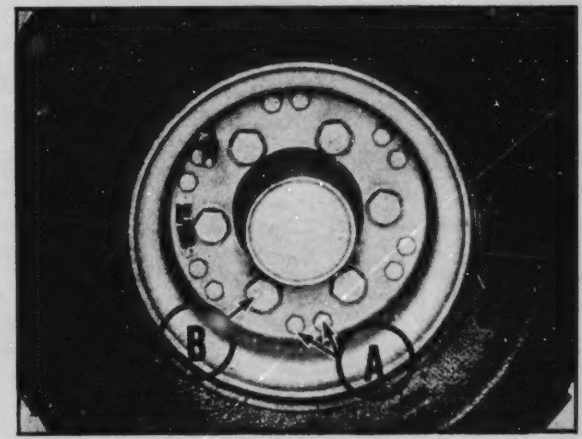
(6-315)
LEFT-HAND THREAD CAP NUT

Courtesy of Budd Company



(6-316)

Courtesy of Kenworth Truck Co.



(6-317) A—Rim half nuts —hold split rims together. B—Hub nuts — hold wheel to hub.

Courtesy of Clarke Equipment Company

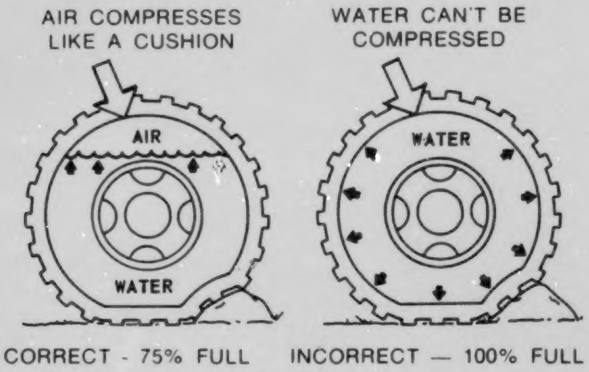
BALLAST

Modern off-the-road machines have adequate horsepower, but the machine weight by itself may not be sufficient to give full traction and drawbar pull. Under only its own weight, the machine's wheels may slip excessively and cause tires to wear rapidly. Extra weight in the form of ballast can give the machine the traction it needs and also reduce tire wear. Farm tractors are one example of a machine that uses ballast.

How much ballast does a machine need? Enough to give good traction and yet allow a small percentage (10-15%) of wheel slippage. There are two types of ballast: liquid and dry.

Liquid Ballast

Liquid ballast is usually a mixture of water and calcium chloride. The calcium chloride adds weight to the water and prevents it from freezing. The mixture is pumped in until the tire is 75 percent full (Figure 6-318). Air is then pumped into the remaining space. A tire is never 100 percent filled with liquid ballast because it would be inflexible and couldn't properly absorb shocks (i.e., water doesn't compress). Filling a tire with liquid ballast is usually done in a tire shop because most heavy duty shops aren't equipped to do it.



(6-318)

Courtesy of John Deere Ltd.

Dry Ballast

Dry ballast, although not as common as liquid ballast, is also used for weighting tires. Some dealers are equipped to install dry ballast and a few manufacturers are installing dry ballast at the factory. Normally, tires are filled to 87 to 95 percent of capacity with a ballast powder made of a clay, limestone and barium sulfate compound. Dry ballast comes in weights of 10, 15 and 20 pounds per gallon for different size machines.

Advantages claimed for dry ballast:

1. Gives 20 to 30 percent more traction with less tire wear.
2. Reduces the inherent bounce in rubber tires, giving smoother operation.
3. Has no freezing problem because it is dry material and is treated to resist moisture.

Disadvantages of dry ballast:

1. Has higher initial cost.
2. Requires outside servicing with special equipment.
3. Looses ballast if tire and tube or valve fails.
4. Causes more heat build-up.

Cast Iron Ballast

Cast iron weights can also be bolted to the frame or wheels to give a machine ballast. The general practice is to first add liquid ballast to tires and then add cast iron weight as required.

Caution: Extra precautions must be taken when removing ballast weighted wheels. Be sure to use adequate slings or lifting devices.

TIRE TRACTION AND PROTECTION DEVICES

Chains

Mud or snow lug tires, under certain circumstances, may not be sufficient to give a machine the traction to keep it moving. In this event traction devices are required. The most common traction device is skid chains. Skid chains are used on two and four wheel drive vehicles operating either on or off the highway. Even tandem drive vehicles will occasionally require chains.

Truck and bus chains for traction in snow, ice, and mud are illustrated in Figure 6-319. Figure 6-320 shows skidder chains.

(6-320)

Courtesy of International Harvester

(6-319)

Courtesy of Dominion Chain Co.

(6-319)

Courtesy of Dominion Chain Co.

(6-319)

Courtesy of Dominion Chain Co.

Chains are used as protection devices as well as for traction. Rock quarry work is extremely hard on tires. To protect tires operating in quarries special chains are made that fit over the entire tread and sidewall. The chain mesh protects the tread from abrasion, cuts and bruises. Quarry chains are expensive, and so their cost and the added life they give to tires must be weighed against simply running the tires to destruction.

Beadless Tires

Caterpillar has developed another traction/protection device called a beadless tire (Figure 6-321), made for loaders working in rock. It is a specially designed one-piece tire having an oval air chamber called a carcass. The carcass is one ply, and instead of beads has a framework of helically wound cable to give it support. The carcass is mounted to a unique two-piece split rim. A replaceable, cable-reinforced rubber belt encircles the outer circumference of the carcass. The belt is held in place by air pressure in the carcass and by matching grooves on the inside of the belt and on the outside of the carcass. Steel shoes bolt directly to anchor plates moulded to the mounting belt. The shoes, belt and carcass are all replaceable.

(6-321) 1—Two piece rim. 2—Carcass. 3—Mounting belt. 4—Shoes. 5—Center mounting bolt.

Courtesy of Caterpillar Tractor Co.

QUESTIONS — TIRES, RIMS AND WHEELS, BALLAST, TRACTION DEVICES

1. List five purposes of tires.
2. What are the two general types of tires and what are the two types of tire construction?
3. What do the following letters and numbers refer to with respect to tire sizing: H.R. 78-15?
4. What is the purpose of tire beads?
5. True or False? Ply-rating gives the strength of the tire, but does not necessarily give the number of cord plies.
6. What is the main advantage of belted-bias and radial-belted tires over bias ply tires?
7. Drive wheel tires with a V-tread pattern must be mounted for forward rotation so the V-pattern points:
   (a) downward as viewed from the front.
   (b) downward as viewed from the rear.
   (c) upward as viewed from the front.
   (d) either (a) or (c).
8. True or False? Tire flaps are needed in tubeless tires to help seal the tire at the rim.
9. What two other factors are considered besides tread design when selecting off-the-road tires?
10. How does a cast spoke wheel with a demountable rim differ from a disc wheel?
11. Briefly explain how the method of retaining the rim on a cast spoke wheel differs from retaining the rim on a disc wheel.
12. What precautions must be observed when removing split-rim wheel?
13. How are the double nuts and studs used to attach disc wheels marked to indicate thread direction?
14. If a machine working in off-the-road conditions has insufficient weight, excessive ______________ of the tires will result.
15. Weight can properly be added to a machine by:
   (a) using flotation tires.
   (b) piling up rocks on the machine.
   (c) filling the tires with liquid or dry ballast.
   (d) inflating the tires.
16. The recommended maximum amount of liquid ballast that can be put into tires is:
   (a) 50% calcium chloride. 50% air.
   (b) 75% calcium chloride, 25% air.
   (c) 90% calcium chloride. 10% air.
   (d) 100% calcium chloride, no air.
17. What precaution must be observed when removing ballast weighted wheels?
18. Tire chains on a grader working in wintery conditions would be needed for __________________. Tire chains on a loader in a rock quarry are used for __________________________________ .
19. What does a beadless tire have in place of tread?

MAINTENANCE AND SERVICE REPAIR ON TIRES, RIMS AND WHEELS

DAILY, ROUTINE CHECKS ON TIRES

1. Check the tires for cuts, gouges, or any other damage that would make the tires unsafe to operate.
2. Remove any rocks that are embedded in the treads. If left in, the rocks can work their way into the plies and weaken them.
3. If rubbing marks are found on a side wall, misalignment or severe suspension wear could be indicated. Find out what caused the rubbing.
4. Abnormal tread wear is usually a sign of misalignment.
5. Check the depth of tire treads. Any vehicle operating under the Bureau of Motor Carrier Safety must have at least one-eighth inch of tread depth on the front tires. When front tire tread wears below one-eighth inch, the tires can be rotated to driving axle or trailer axle positions until one-sixteenth inch of tread depth remains. Tires with less than one-sixteenth inch tread must be removed from service.
6. Check for any part of the machine that could damage or cut a tire — a bent fender, a bolt, a broken support part, a bent rim.
7. Check tire pressure. A quick method used by those who have a feel for a properly inflated tire is to hit the tires with a bar. From experience they can tell if the pressure is right. However, the only sure way to check tire pressure is with a tire gauge.

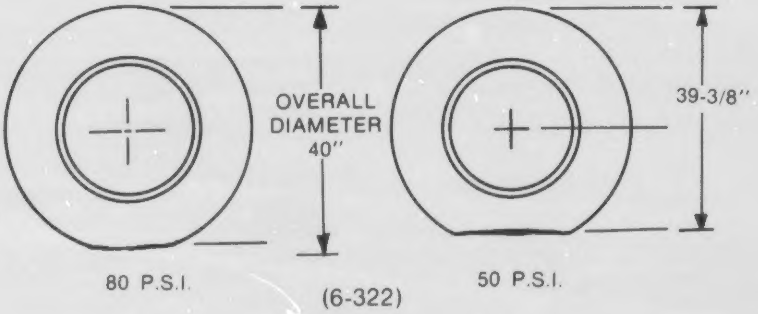
Maintaining the correct air pressure is an important tire maintenance procedure. Some of the reasons for closely watching tire pressure are shown on the following page.

Effects Of Incorrect Inflation

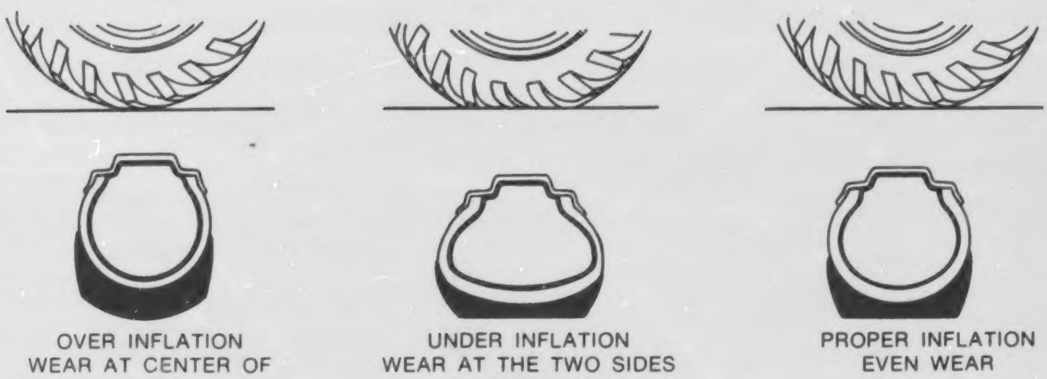
Attention to tire pressures on the front wheels is as important to the safe control of the truck as is tire balance and front-end alignment. With lower pressure, tire contact area with the road increases. More contact area means more resistance against rolling and poorer fuel mileage. If front tire pressures are unequal, the wheels will tend to steer to the side of lowest pressure causing extra tread wear. Such a steering pull may not be noticed when driving with power-assist steering until the brakes are applied. During braking application the tire with the lowest pressure will pull the truck to its side. A sudden, hard application of the brakes on a slippery road might start a tractor-trailer rig jack-knifing.

Consider the change in the overall diameter of two similar tires with different tire pressures (and constant load) (Figure 6-322). The lower the air pressure the shorter the overall diameter becomes. Since the overall diameter is smaller in the under inflated tire, it will travel more revolutions in a mile (i.e., faster at constant speed), in this case about 22 extra revolutions. If this underinflated tire was matched with a correctly inflated tire on one side of a tandem, the under inflated tire would slip for those 22 revolutions because it must travel at the same speed or revolutions per mile as the correctly inflated tire. During the first 1,000 miles it will slip 13-1/2 miles, and after 10,000 miles it will have slipped 135 miles. Tire treads have been known to be ground off in less than 10,000 miles.

Under inflation can affect more than the tread of a tire. Under inflated tires flex excessively and this results in high internal tire temperatures that can cause premature tire damage such as flex breaks, radial cracks and ply separation. Over inlfation is also bad for tires. It prevents full contact of the tire with the ground causing excessive wear at the center of the tread. An over inflated tire is too rigid and is more vulnerable to snags, cuts, and punctures. Figure 6-323 illustrates over, under and proper inflation. Note that a proper inflation permits all of the tread to contact the ground, but doesn't allow the tire to flex excessively.



(6-322)



OVER INFLATION
WEAR AT CENTER OF
TIRES

UNDER INFLATION
WEAR AT THE TWO SIDES
OF THE TREAD

PROPER INFLATION
EVEN WEAR

(6-323)

Courtesy of John Deere Ltd.

SERVICE REPAIR OF TIRES AND RIMS

This section is mainly concerned with removing and installing wheels and with wheel, rim and stud damage. It does not deal with changing tires because most tire work for heavy duty vehicles will be done by tire specialists.

Removing Tires and Wheels

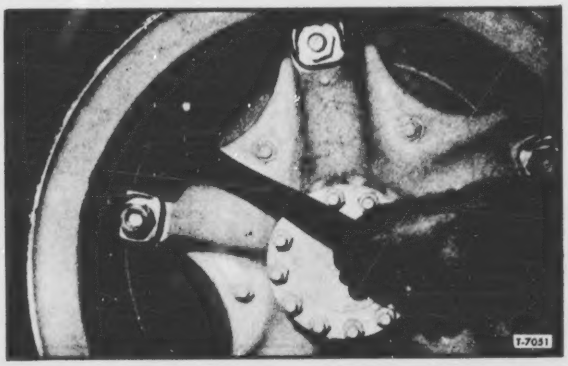
Jacking Precautions

1. Regardless of how hard or firm the ground appears, put a good solid block(s) under the jack.
2. Block the tire and wheel on the other side of the vehicle before you place the jack in position. Always crib up with blocks just in case the jack may slip.

Removing Wheel Nuts

The correct way of removing wheel nuts is to first loosen all the nuts in the same pattern that they are tightened and then to remove them.

Caution: When removing single and dual cast spoke wheel rims and tires, loosen all nuts until they are approximately flush with the end of the stud. Then strike the clamps with a hammer to loosen them from the rim (Figure 6-324). This will prevent the clamps from flying off the studs when the nuts are removed.



(6-324) CLAMP REMOVAL (DUAL SPOKE WHEEL)

Courtesy of General Motors Corporation

Tire Heat

Under normal working conditions a tire will heat and its air pressure will increase. If air pressure is taken during a shift, the reading will be higher than the air pressure really is. If the tire was then mistakenly bled to bring it down to specified pressure, it would be under inflated. Tire pressure, therefore, must be checked on cold tires.

The best time to take tire pressures is in the morning before the shift begins, after the tires have had a chance to cool down overnight. However, some machines run for two or three shifts in a day and are not idle long enough for the tires to cool. In this case get a correct cool tire reading, and then take a hot reading at least two hours into the shift. This hot reading is what the tire pressure should be when measured hot thereafter.

Tires are built to take a certain amount of heat, but too much heat can damage the structure of the tire. One of the factors, already discussed, that cause a tire to overheat is under inflation. Other factors are overloading and high speed. Their effect on tire heat can be seen in the following statistics. The temperature of a tire with a normal load at 60 MPH is approximately 212°F. When the speed is increased to 80 MPH, the temperature will rise to 250°F. An overload of 20 percent will produce 250°F. at 70 MPH. This may help to explain why many tires fail in the summer months.

Overheating is especially damaging to large off-highway tires. Although big heavy duty tires are built to take rough physical treatment, they cannot stand too much heat. Their thick rubber construction has a tendency to withhold heat. To avoid a damaging heat buildup when driving an off-highway machine on the highway, it should be stopped every 25 miles (or one hour) for a half hour to cool the tires.

Tire Pressure Gauges

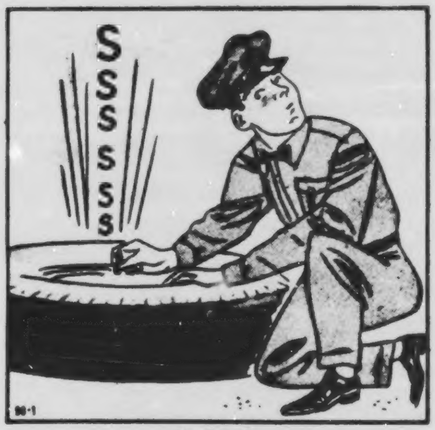
Two types of pressure gauges are usually available — high-pressure and low-pressure — for either dry or liquid testing. Always use the proper gauge when checking pressure. High-pressure gauges will be used on most truck and off-highway machine tires. Normally, high-pressure gauges are not satisfactory for checking low-pressure tires because the gauges are usually calibrated in five-pound increments while low-pressure gauges are calibrated in one-pound increments.

It is most important that a gauge be accurate. Accuracy can only be determined by checking the gauge against a gauge of known accuracy. For this reason, keep one accurate gauge for the sole purpose of checking the accuracy of the gauge normally used. This practice is especially important when working with low-pressure gauges.

Deflating and Inflating Tires

Tires should be deflated, if possible, before removing them from the vehicle. To deflate the tire, first reduce pressure by pushing in the valve plunger, and then remove the entire core to ensure complete deflation.

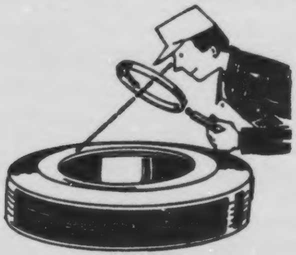
Caution: When deflating a tire, keep your eyes away from the valve, and never place your body in front of the rim (Figure 6-325). Also, never attempt to unlock or remove a lock ring without first removing the valve core.



(6-325)
Courtesy of Mack Truck Ltd

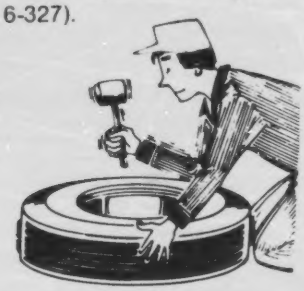
Inflating Tires

1. Before inflating a tire make certain the rim lock ring is seated to the full depth of the groove, fits tightly all around, and is securely locked (Figure 6-326). Improperly seated rings are a main cause of rim failure.



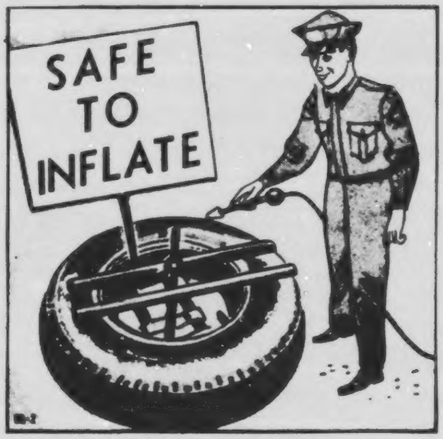
(6-326)
Courtesy of General Motors Corporation

2. Use a rubber covered steel hammer on rims and tires; it won't damage the rim or chip off bits of metal that may cause injury (Figure 6-327).

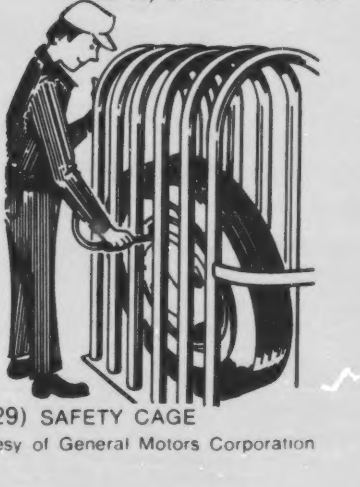


(6-327)
Courtesy of General Motors Corporation

3. Do not attempt to correct side and lock ring seating by hammering a tire while it's inflated or partially inflated. Remove all the air pressure first.
4. If possible use a safety device such as is shown in Figures 6-328 and 6-329 when inflating a tire:



(6-328) SAFETY PRESS
Courtesy of Mack Truck Co



(6-329) SAFETY CAGE
Courtesy of General Motors Corporation

5. If it is not possible to use a safety device use a self attaching air chuck and stand behind the tire tread while inflating.

⚠ WARNING

Use self-attaching air chuck and stand behind tire tread while inflating.

(6-330)

Courtesy of Caterpillar Tractor Co

6. The valve core is a spring-loaded check valve in the valve stem, permitting inflation or deflation of the tube or tire. This check valve, or core, is not intended to hold the air during operation. The valve cap is provided to seal the air in the tube and tire. When the valve cap is tightened on the stem, the sealing washer inside the cap is pressed tightly against the top of the stem, preventing air leakage and keeping dirt out. It is important, therefore, that valve caps be used at all times. Note that most valve caps used for automobile tires are made of plastic and won't give a seal. They only protect the core from dirt and contamination.

SCHEDULED MAINTENANCE ON TIRES

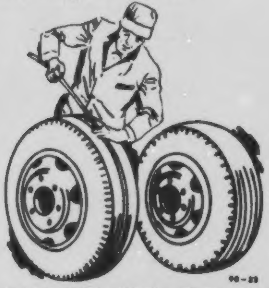
Probably the main form of scheduled maintenance on tires is matching the tires. Tires should be matched when put on a vehicle and matched thereafter on a scheduled basis. Mismatched tires can cause a lot of problems. Consider this extreme example:

Imagine a set of tandem axles, directly connected by the prop-shaft, rolling on eight tires all of a significantly different radius. The rear axle will try to over-run the forward axle and the forward axle will try to hold back the rear axle. The tires will squirm and scrub. This is wheel fight. It tries to wind up the prop shaft and twist the axle shafts. Wheel fight causes the ring and pinion gear teeth to grind under extreme pressures and the differential and bearings to work beyond their normal limit. If these conditions are allowed to continue, internal mechanical damage will surely result.

How To Match Tandem Tires

The vehicle should be on a level floor, carrying a correctly distributed capacity load. Be sure all tires are the same size.

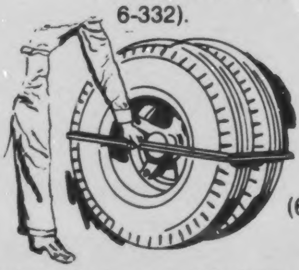
1. Inflate all tires to the same pressure.
2. Tire measurements:
   (a) The most accurate method of measuring tires is to measure, with a steel tape, the circumference of the tires when they are on the rim and inflated (Figure 6-331).

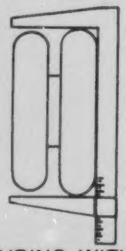


(6-331) MEASURING WITH FLEXIBLE TAPE

Courtesy of Mack Truck Company

   (b) Taking circumferences is difficult when the tires are on the vehicle. In this case measure the radius or the diameter of the tires. A large square, matching stick or string line is suitable for this measurement (Figure 6-332).





(6-332)

MEASURING WITH A SQUARE

MEASURING WITH MATCHING STICK

Courtesy of Mack Truck Company

3. Mark the size on each tire with chalk and arrange them in order of size, largest to smallest.
4. Mount the two largest tires on one side of one axle and mount the two smallest on the opposite side of the same axle. It is advisable to allow only a half inch difference in diameter between duals, or one and a half inch difference between circumferences.
5. Mount the four other tires on the other axle in the same manner. If the vehicle has tridem axles, the same system is used: arrange the tires in order of size. The two largest and two smallest go on one axle, the next two largest and smallest go on the second axle, and the remaining four go on the third axle. This system of matching has two benefits:
   - (a) each running pair is closely matched.
   - (b) the total rolling circumference of the four tires on an axle will be approximately the same for all axles.
6. Test run the vehicle to get accurate rear axle lubricant temperature readings on the two axle lubricant temperature gauges. Vary tire air pressure, within the tire manufacturer's recommended range, so that the lubricant temperatures of both axles are within 30°F. of each other and not in excess of 220°F. This will usually result in uniform tire loading and good tire life.

Tire Rotation

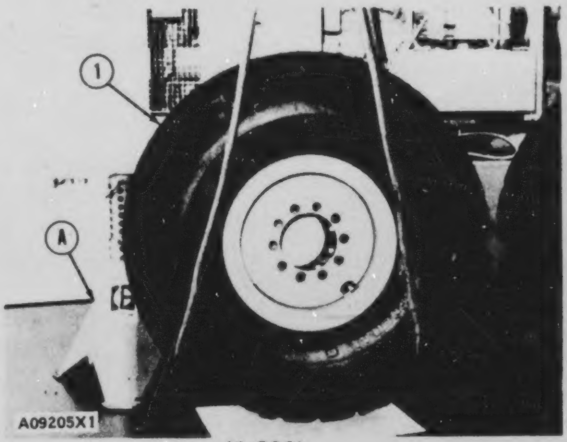
Generally speaking, if a tire is broken in on the front wheels and then moved to the rear axle(s), it will have a longer overall service life. For this reason, some fleet owners will rotate tires from front to rear wheel positions on a scheduled rotation plan. The plan will vary depending on the type of vehicle and the size of tires. Note that any tire that has been recapped or regrooved should not be used on the front of a vehicle. Heavy duty tires and wheels can be put into three size categories according to the way they're handled.

1. **Over-the-highway truck tires**

   These tires can be lifted off studs and rolled out of the way by hand. Wheel dollies are also used for handling highway truck tires.

2. **Tires for construction equipment such as larger wheel loaders or graders**

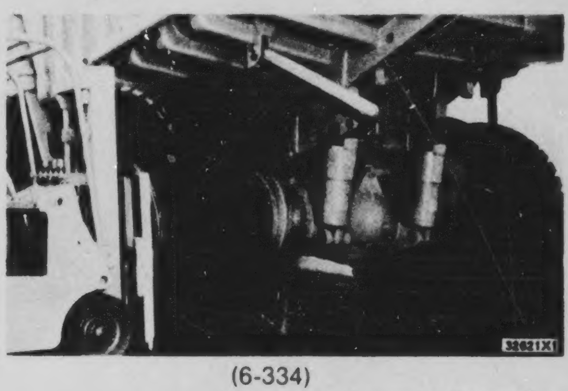
   These tires and wheels are large enough to be dangerous if they fall over and thus require a forklift or an overhead crane and sling to remove and to move them (Figure 6-333).



(6-333)
Courtesy of Caterpillar Tractor Co

3. **Tires and wheels for large off-highway haulers in the 100-200 ton range**

   These tires and wheels are very large and heavy; a forklift (Figure 6-334) with a tire attachment is generally used to remove them from the machine. Slings are also used.



(6-334)
Courtesy of Caterpillar Tractor Co

Take special precautions with ballast weighted tires. Injury could result from a tire that looks like it could be handled by hand but can't because of the extra weight of internal ballast. If you do not know whether a tire has internal ballast, check the air valve. Internal ballast requires a special type of valve. Also be careful of external weights attached to the wheel by the wheel lugs. By thoughtlessly removing these lugs, you could have the weights fall on your foot.

MOUNTING WHEELS

Before Mounting Wheels

1. Free the mounting surfaces of dirt, paint, burrs, etc., so that there is good wheel to hub or wheel to wheel contact. Also clean the wheel nut ball seats.
2. Clean the stud threads and check them for wear at the mounting face.
3. Be sure that the end of the nut has no burrs, especially when tightening nuts on aluminum wheels. The burrs could gouge the aluminum and cause the wheel to crack under stress.

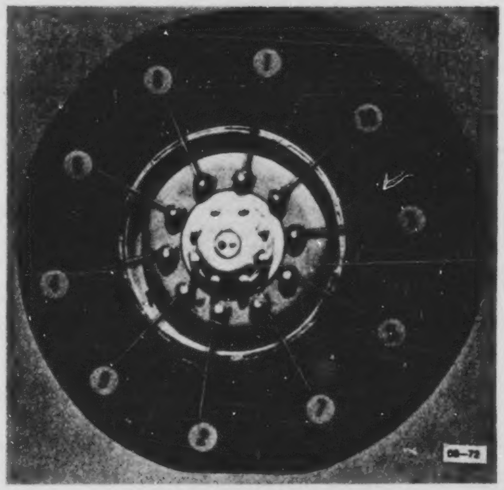
Torquing Nuts

When tire and rim problems occur, incorrect installation and tightening practices are often the cause.

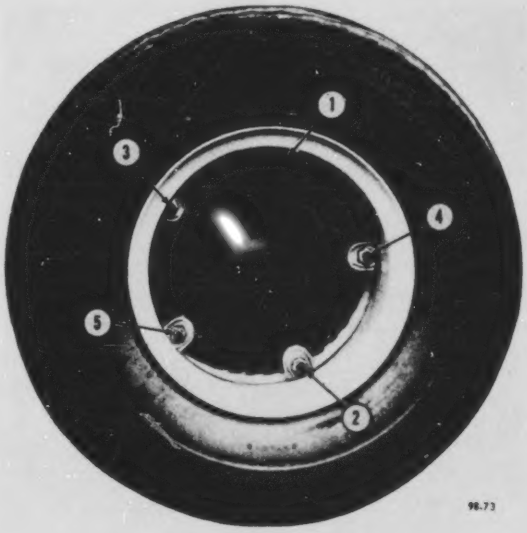
1. Wheel nuts must be torqued:
   - (a) in the correct sequence.
   - (b) in several stages to the correct torque specifications.

   Figure 6-335 shows the torquing sequences of a five point spoke wheel and a ten stud disc wheel. Note the pattern of torquing opposite nuts in sequence.

2. In most cases wheel nuts and studs should be clean and dry; they shouldn't be lubricated. The exception is on aluminum wheels and on seized or frozen nuts.



(6-335)
Courtesy of Mack Truck Company



(6-335)
Courtesy of Mack Truck Company

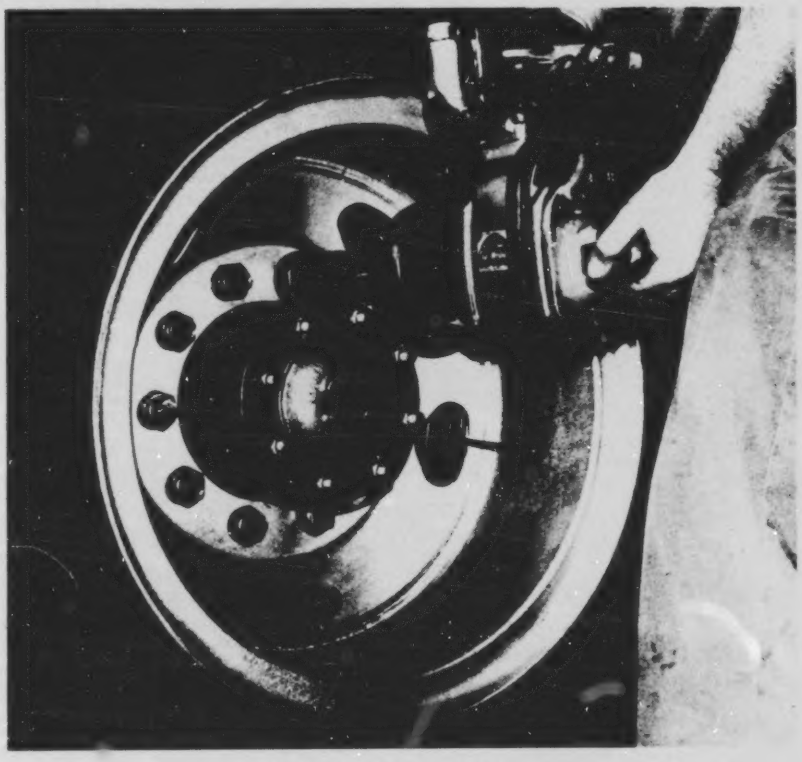
3. Tightening procedure:

   (a) The first time around and in the proper sequence lightly tighten nuts with a wheel wrench so that the wheel is seated on the hub disc wheels, or the rim is seated on the wheel for spoke wheels.

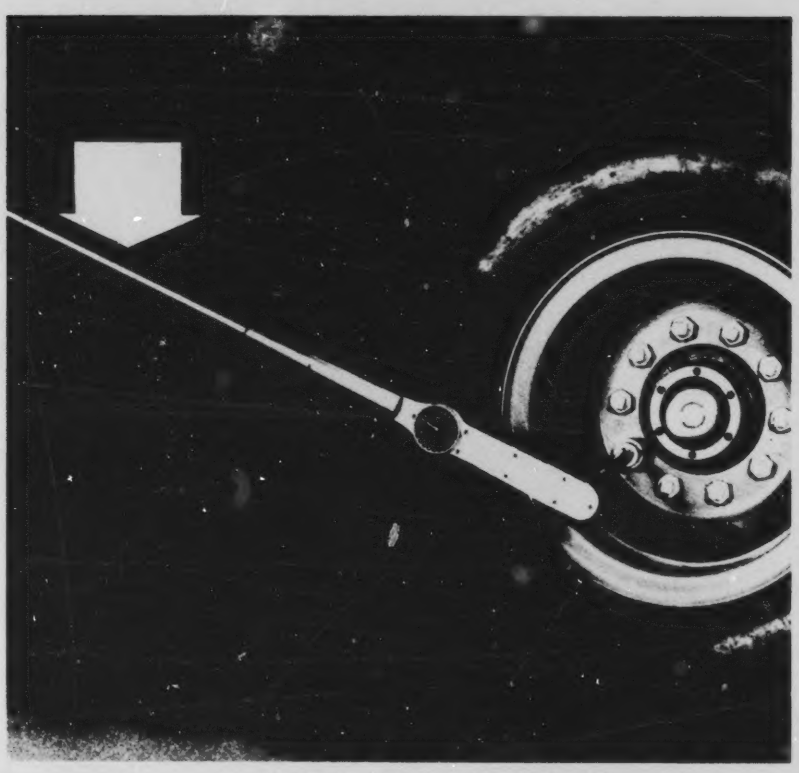
   (b) On the second round, tighten the nuts with a wheel wrench or air wrench (Figure 6-336) so that the rim or wheel is correctly positioned and snug.

   (c) Finally, tighten the nuts with a torque wrench (Figure 6-336) to the torque specified in the manual. Excessive tightening can distort the wheel or cause inconsistent brake action, while under torquing can cause the wheel to loosen. Avoid these problems: use a torque wrench.

Note: On disc wheels having an inner and outer nut these three procedures would be gone through twice, once for the inner nut and once for the outer nut.



(6-336) AIR WRENCH Courtesy of Budd Company



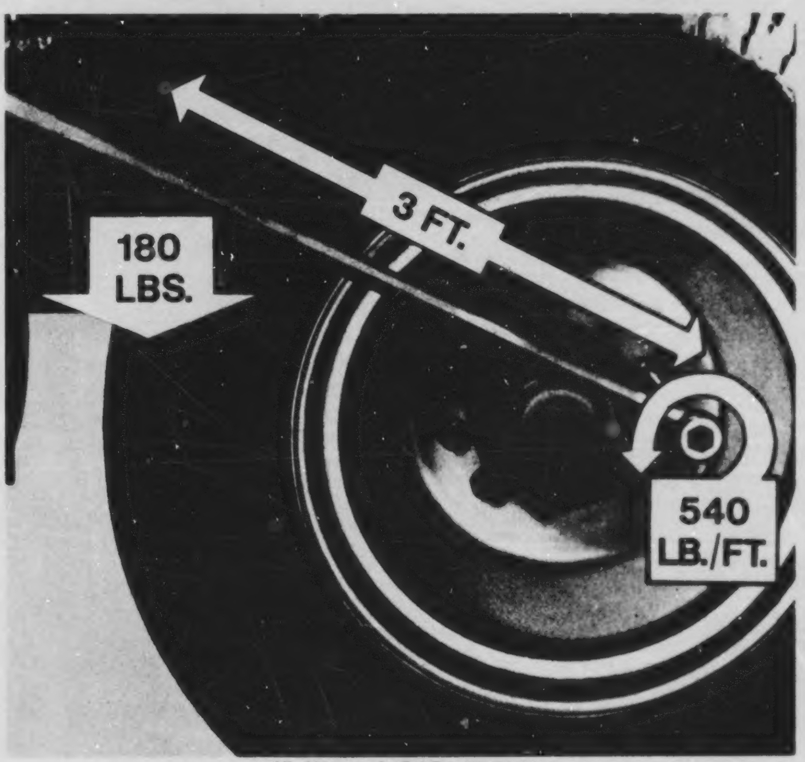
(6-336) THE TORQUE WRENCH

Courtesy of Budd Company

4. As stated above the most accurate way to tighten wheel nuts is with a torque wrench. However, if a torque wrench is not available, a fairly close feet-pound approximation can be achieved with a standard wheel wrench. Since feet-pounds of torque is nothing more than weight applied in pounds times distance in feet, the mechanic weighing 180 pounds steadily applying his full weight three feet out on the wrench handle (Figure 6-337) until the cap nut will no longer tighten will have 540 feet-pounds of torque. A 200 pound man applying his weight 2-1/2 feet out on the extension would get 500 feet-pounds of torque.

6. To properly check the torque of previously tightened nuts, a torque wrench should be used. Apply the torque wrench on a previously tightened nut and at the point the nut starts to turn read the torque indicated on the gauge.

7. An accurate reading cannot be obtained on the inner cap nuts without loosening the outer cap nuts. Back off the outer cap nuts a few turns, and check the torque of the inner cap nuts. Then retighten the outer cap nuts to the specified torque.



(6-337) A BAR WRENCH
HOW TO USE A STANDARD WHEEL WRENCH
(Assuming specified torque is 450 pound-feet)

Courtesy of Budd Company

5. If a spongy feel is obtained when the cap nuts are tightened, or if the nuts cannot be pulled into a solid seat, something is wrong. The assembly should be checked, with wheels dismounted, for evidence of worn ball seats, damaged studs or defective wheel nuts.

8. A check should be made for tire runout (a wabble in the wheel) after the wheel stud nuts have been torqued (Figure 6-338). All wheels are susceptible to run out from improper tightening, and spoke wheel more so than others.

Rim Alignment Checks

After assembly of rims to wheels, rotate the wheels and check alignment. Use a block of wood or other object to support marker so the marker is at the same level as the edge of the rim (Figure 6-338). Rotate the tire/wheel assembly and note variations in the space between edge of rim and edge of marker as the assembly is rotated. Variations in excess of 3/32" for front assemblies or 3/16" for rear duals indicate the rim is not properly mounted.

To correct any misalignment, loosen nut at greatest variation and tighten nut on opposite side. Recheck and correct until runout is within above recommended limits.

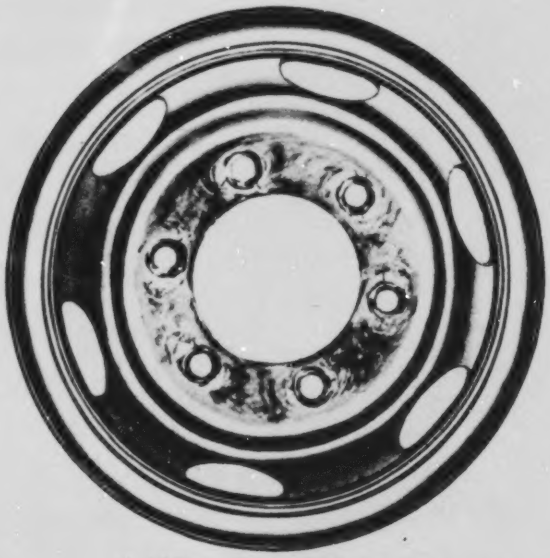
DAMAGE AND REPAIR OF RIMS, STUDS AND HUBS

Below are examples of worn or damaged rims, studs, hubs. The general rule of wheel repair is to replace weak or damaged parts. Don't attempt to straighten badly dented or distorted wheel parts. Also, don't attempt to weld, heat, or braze any wheel parts.

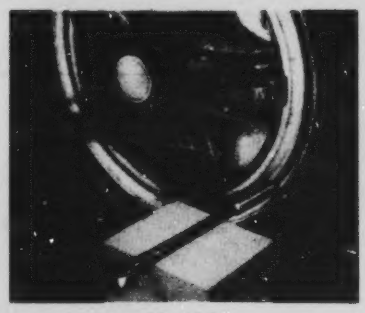
1. Worn wheel stud holes — out of round stud holes and metal build up around outer edge of each hole (Figure 6-339).

   Cause: wheels working against each other or loose nuts.

   Service: replace wheels and nuts.



(6-339) WORN STUD HOLES



SPACE VARIATION BETWEEN EDGE OF OUTER FLANGE WALL AND EDGE OF MARKER NOT TO EXCEED 3/32" FOR FRONTS OR 3/16" FOR REAR DUALS

DO NOT GAGE TO EDGE OF FLANGE

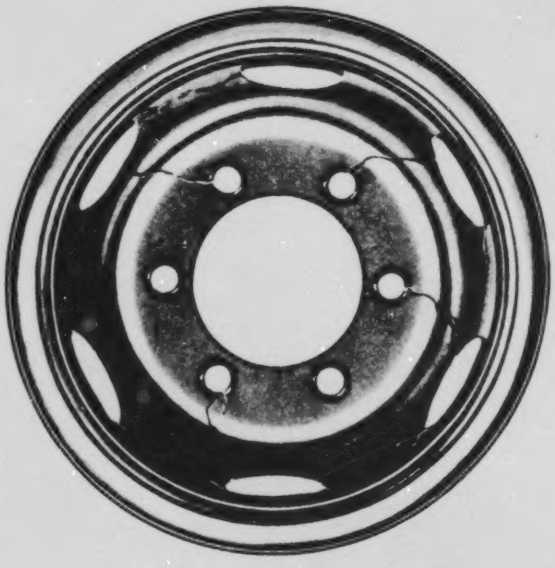
(6-338)

Courtesy of Dayton-Walther

2. Cracks: various crack patterns are shown in Figure 6-340.

   Cause: overloading, loose mounting.

   Service: replace wheel and also nuts damaged.



(6-340) CRACKED WHEELS

Courtesy of Budd Company

3. Bent, damaged, rusted rims.

Cause: overloading, hitting obstacles, being constantly wet.

Service: minor dents can be hammered out. Replace the rim if it has major damage. Similarly, minor corrosion should be scraped or brushed off and the surface painted with corrosion resistant paint. A rim with serious corrosion should be replaced.

4. Damaged rings. Rings can get cracked, broken, bent, corroded. Damaged rings are a common cause of rim failure.

Cause: rough use of tire tools, improper seating, hitting obstacles, being constantly wet.

Service: replace rings.

Note: Before any rim or ring is reused, it must be thoroughly cleaned. Dirt, rust, and other foreign matter must be removed from its surface. Pay particular attention to seating surfaces and bead seat areas.

5. Stripped studs (Figure 6-341).

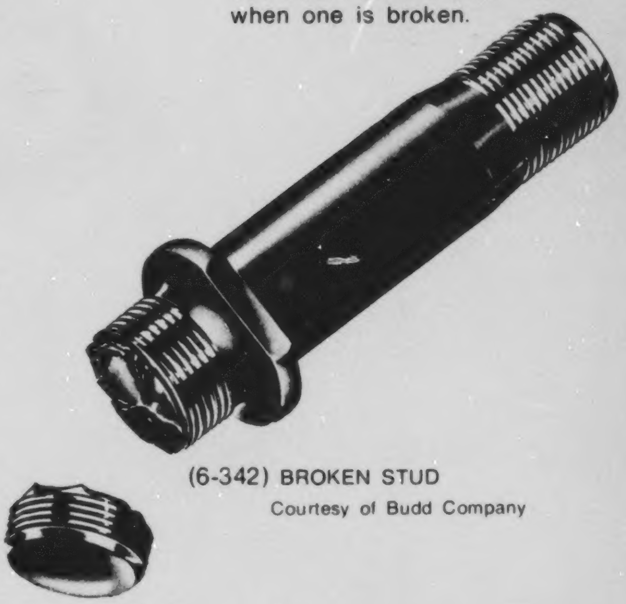
Causes: excess torquing of wheel nuts or damaging the threads when putting the wheel over the studs.

Service: replace.

6. Broken studs (Figure 3-342).

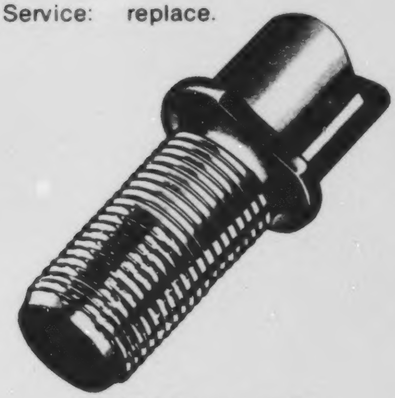
Cause: loose wheel nuts, improperly seated wheels.

Service: replace stud. When a broken stud is found on a ten-hole mount, the correct practice is to also replace the studs on each side of it (Figure 6-343). In smaller hole mounts all the studs would be replaced. These extra replacements are necessary because of the undue strain on the other studs when one is broken.



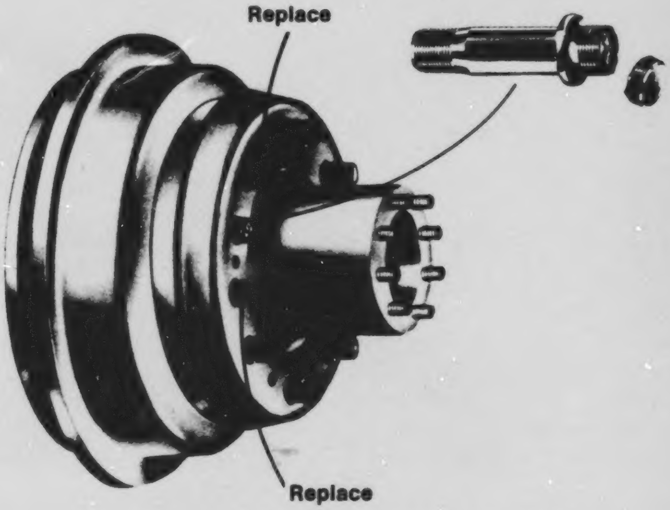
(6-342) BROKEN STUD

Courtesy of Budd Company



(6-341) STRIPPED

Courtesy of Budd Company



(6-343) Courtesy of Budd Company

7. Damaged inner or outer wheel nuts.

   Cause: loose mounting.

   Service: replace nut and possibly the stud.

8. Seized nuts.

   (a) Cause: corrosion or friction seizing.

   Service: lubricate first three threads of nuts and studs. Do not use penetrating oil. Be sure to keep the lubricant off the ball seat of the stud holes and ball face of the cap nut.

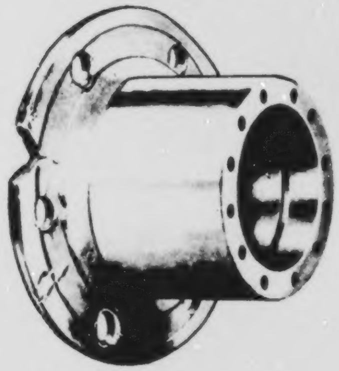
   (b) Cause: under torqued inner nut.

   Service: torque inner nut to correct pressure.

9. Broken, cracked or worn hub face (Figure 6-344).

   Cause: loose wheel assembly.

   Service: superficial face wear can be repaired by machining the surface flat. A hub with cracks or breaks must be replaced.



(6-344)

Courtesy of Mack Truck Company

SERVICE OF TRACTION DEVICES

Inspection

Chains

Inspect chains for wear, damaged links, broken cross-links. The amount of service life left in chains can be estimated by comparing the thickness of worn cross-links to the thickness when new. (A link that attaches the cross-link to the side link would be relatively unworn and can be taken for new thickness.) Broken cross-links should be repaired, especially if the chains are used on a fast moving vehicle such as a truck. A length of cross-link flying around could damage brake lines and other parts around the wheels.

Beadless Tires

When inspecting a beadless tire check:

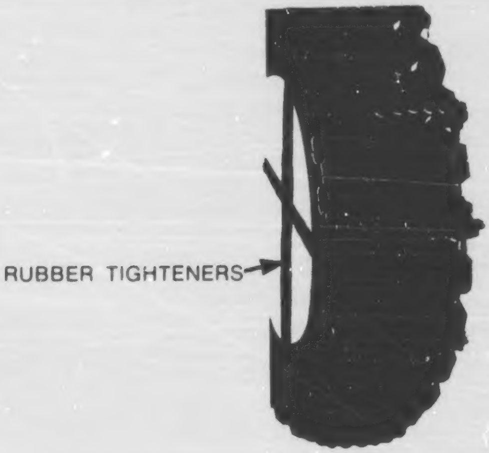
1. the side walls of the carcass for cuts, damage.
2. the mounting belt for damage.
3. the track shoes for looseness. Also check for worn cracked, damaged, missing shoes.

The height of the grouser bars should also be measured and when worn below a certain limit (see service manual) they should be replaced.

Installing Chains

Skid chains may be installed in one of two ways. In a shop, jack or lift the vehicle so it clears the ground. Then place the chain over the top of the tire and latch the ends of the side links together at the bottom. The chain cross-links must then be positioned around the lugs of the tire so that they lay as straight as possible across the face of the tire. Retighten the couplers so that the chain is snug but not too tight. A word of advice: putting on chains is more difficult than it sounds, especially on large wheels.

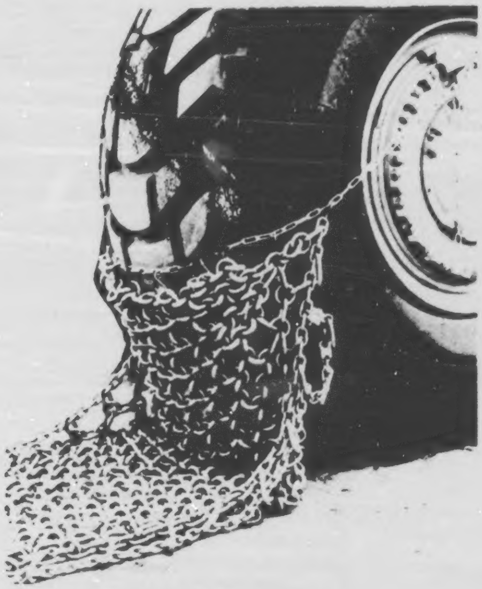
To put on chains on the road, lay the chain out flat in front or rear of the tire and run the tire onto the chain a foot or two from the end. The other end of the chain is then dragged over the top of the tire so the two ends can be coupled together. Chains are heavy and often there are obstructions like fenders that make it difficult to work the cross-links around so they lay straight enabling the side links to be snugged up. A bar will often help in working the chain into position. Once the chain is coupled, moving the vehicle back and forth will aid in positioning the chain and will take out the slack. To help tighten chains, chain tighteners can be made from strips of old inner tube with hooks on each end. On each chain two tighteners are attached to the side links in a diagonal (Figure 6-345).



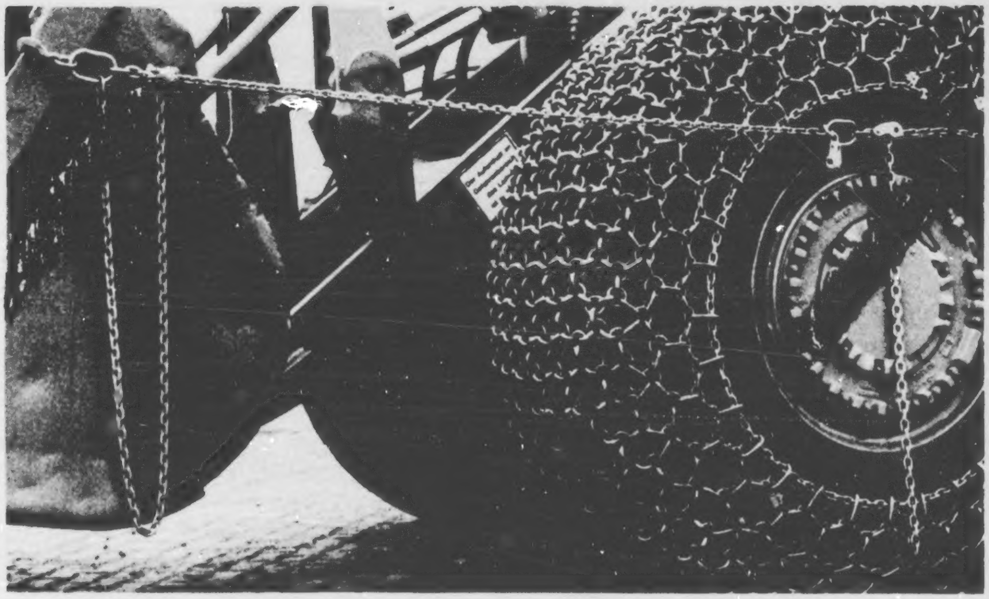
(6-345)

Courtesy of Dominion Chain Co.

Protection chains, due to their weight, are more difficult to install than traction chains. Figure 6-346 shows how the chains can be installed by hooking one end to a small chain tied part way around the tire. The machine is then backed up to drape the chain around the tire. Final hooking is done with the aid of the loader's hydraulics. In a shop, these protection chains can be installed by jacking up the machine and lifting the chains onto the tire with a hoist. The method above, though, is probably the easiest.



(6-346)



QUESTIONS — TIRES, RIMS, WHEELS MAINTENANCE AND REPAIR

1. Low tire pressure causes:
   (a) increased tire contact with the road.
   (b) increased rolling resistance.
   (c) increased tire heat due to flexing.
   (d) only (a) and (c) are correct.
   (e) (a), (b) and (c) are all correct.
2. When is the best time to take tire pressure?
3. What is rapid heat build-up in heavy equipment off-the-road tires caused by?
4. When inflating a tire, what precautions **must** be taken?
5. When matching tires on a tandem truck, the allowable difference in tire circumferences is:
   (a) 1/4"
   (b) 3/4"
   (c) 2-1/2"
   (d) 1-1/2"
6. True or False? A recapped or regrooved tire should not be used on the front of a vehicle.
7. What is the minimum depth of tread allowed by safety standards for front tires?
8. When installing wheels, the nuts should be tightened in a:
   (a) circular pattern clockwise.
   (b) circular pattern anti-clockwise.
   (c) crisscross pattern, tightening opposite nuts in sequence.
   (d) Any of the above.
9. A ___________ wrench is recommended for final tightening wheel nuts.
10. When removing rims and tires from dual cast spoke wheels what is a good practice to follow before removing the lug nuts?
11. Wheel and tire runout can be caused by:
    (a) improperly adjusted wheel bearings.
    (b) a bent wheel.
    (c) an improperly tightened wheel.
    (d) a faulty tire.
    (e) all of the above can cause runout.
12. What is the general rule of repair for worn or damaged rims, studs, nuts and hubs?
13. If one stud breaks on a ten stud disc wheel, the accepted practice is to:
    (a) replace all the studs.
    (b) replace the broken stud and the two studs on either side of it.
    (c) replace the broken stud and the stud 180° opposite it.
    (d) change at least five studs.
14. True or False? When installing wheel nuts, they should be clean and dry, and not lubricated.
15. How do you check the torque of a previously tightened nut?
16. Why should broken cross-links on chains be fixed immediately?

ANSWERS — TIRES, RIMS AND WHEELS, BALLAST, TRACTION DEVICES

1. — Support the machine.
   — Give traction.
   — Provide flotation.
   — Absorb or cushion shocks.
   — Provide a replaceable wear surface.
2. Over-the-road tires; off-the-road tires.
   Tube, tubeless.
3. H — Load range.
   R — Radial ply.
   78 — Height to width ration.
   15 — Rim size.
4. The tire bead:
   — is the base to which all the tire plies are tied.
   — anchors the tire to the rim besides maintaining the shape and fit of the tire on the rim.
5. True.
6. Less damaging heat build-up.
7. (a) downward as viewed from the front.
8. False.
9. Load size and vehicle speed.
10. The cast spoke wheel and rim are two separate parts, whereas the disc wheel and rim are one.
11. The rim (or rims on dual wheels) for a cast spoke wheel is retained by lugs and nuts. Disc wheels, on the other hand, are retained by ball seat cap nuts which are threaded to studs in the hub. Dual disc wheels have an inner and outer nut arrangement.
12. There are two sets of nuts: nuts holding the split wheel together and nuts holding the wheel to the hub. Know which is which. Removing the split wheel nuts thinking they are the hub nuts could cause serious injury. To play it safe, deflate the tire before removing the wheel.
13. They are stamped with an "R" or "L" or with the words Left or Right. Left hand thread nuts can also be nicked at the corners in a circular pattern around the nut.
14. . . . slippage . . . .
15. (c) filling the tires with liquid or dry ballast.
16. (b) 75% calcium chloride, 25% air.
17. Use adequate lifting equipment.
18. . . . traction. . . . protection.
19. A beadless tire carcass has a belt around the circumference to which steel shoes are attached.

ANSWERS — TIRES, RIMS, WHEELS MAINTENANCE AND REPAIR

1. (e) (a), (b) and (c) are all correct.
2. After the tires have had a chance to cool down. If pressure is taken when the tires are hot, the reading will be higher than it actually is.
3. Excessive speed, over-loading, and under-inflation.
4. (1) Make sure the lock ring is properly seated before inflating.
   (2) Use an inflating cage or a press when inflating the tire, or use a self-attaching air chuck and stand to one side.
5. (d) 1-1/2"
6. True.
7. 1/8".
8. (c) Crisscross pattern, tightening opposite nuts in sequence.
9. . . . torque . . . .
10. Loosen the nuts and tap the lugs with a hammer to ensure that the lugs are loose before removing the nut.
11. (e) all of the above can cause runout.
12. Replace any damaged, weak or worn parts.
13. (b) Replace the broken stud and the two studs on either side of it.
14. True.
15. Apply a torque wrench to the nut, and when the nut starts to turn, note the torque reading.
16. The cross-link flying around could damage brake lines and other parts around the wheel.

TASKS — TIRES, RIMS AND WHEELS, TRACTION DEVICES

DAILY, ROUTINE MAINTENANCE CHECKS

1. On a wheel vehicle commonly found in your shop, check tire pressures, and also check the tires for wear, cuts, or damage. Change or report unsafe tires.

SCHEDULED MAINTENANCE

1. Match the tires on the rear wheels of a tandem drive truck:
   (a) Measure the rolling circumference of all tires on the drive axles.
   (b) Match the tires in sets of two so that the circumferences of both tires are within 1-1/2 inches.
   (c) Rearrange the tires on the vehicle, putting the matched tires together. Install and position the wheels tightening the wheel nuts in the proper sequence to the correct torque.

SERVICE REPAIR

1. Inspect the rims on a wheeled vehicle for cracks, bends, or other damage. Check the condition of the locking ring. Check for worn or damaged studs, bolts, mounting holes, retaining lugs. Make any necessary repairs or replacements or report damage that makes the vehicle unsafe to operate.

2. Using the correct tools, lifting equipment, and procedures, remove demountable rims and tires from a vehicle with single and dual mountings. Do the same with a vehicle that has disc rims. Also install and position the wheels, tightening the wheel nuts in the proper sequence and to the correct torque. Note that part of this task will have been done in task 1 (c).

   Caution: (a) Because ballast weighted wheels (either internal or external ballast) are very heavy, practice safety when removing and installing them.

   (b) Practice safety when removing split rim wheels. Make sure you remove the hub bolts and not the split rim retaining bolts (see manual to distinguish). If in doubt deflate the tire before removing it.

3. If chains are available, inspect them for wear, cracked or broken links or missing sections. Make any needed repairs. If a Caterpillar loader with beadless tires is available, inspect the tires for severely worn, cracked, broken or missing shoes. Also check to see that the shoes are tight. Replace any shoes that are not serviceable. Check the carcass. If it has to be replaced completely deflate it before removing the rim half bolts.

BLOCK

6

Wheel Machine Final Drives

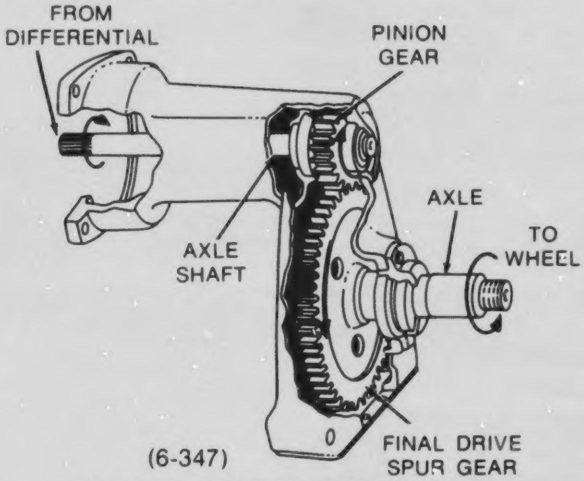
PURPOSE OF WHEEL FINAL DRIVES

The purpose of final drives on wheel machines is similar to those on track machines: to decrease speed to the drive wheels while simultaneously increasing wheel torque or turning power. There are three main types of wheel final drives:

- — single reduction spur gear
- — sprocket and chain
- — planetary (inboard and outboard)

SINGLE REDUCTION SPUR GEAR FINAL DRIVE

Single reduction spur gear final drives are mainly used on farm tractors, although they are also used on some graders and on some large off-highway rear dump trucks. Spur gear final drives operate on the basic gear principle that when a small gear drives a large gear, the RPM's of the large gear decreases while its torque or turning power increases. Power is supplied by the axle shaft to the drive pinion gear which meshes with the large final drive gear. Both gears are supported by bearings; a short axle shaft that may be part of, or splined to, the final drive gear transmits power to the wheel (Figure 6-347).


FROM DIFFERENTIAL
PINION GEAR
AXLE
TO WHEEL
AXLE SHAFT
FINAL DRIVE SPUR GEAR

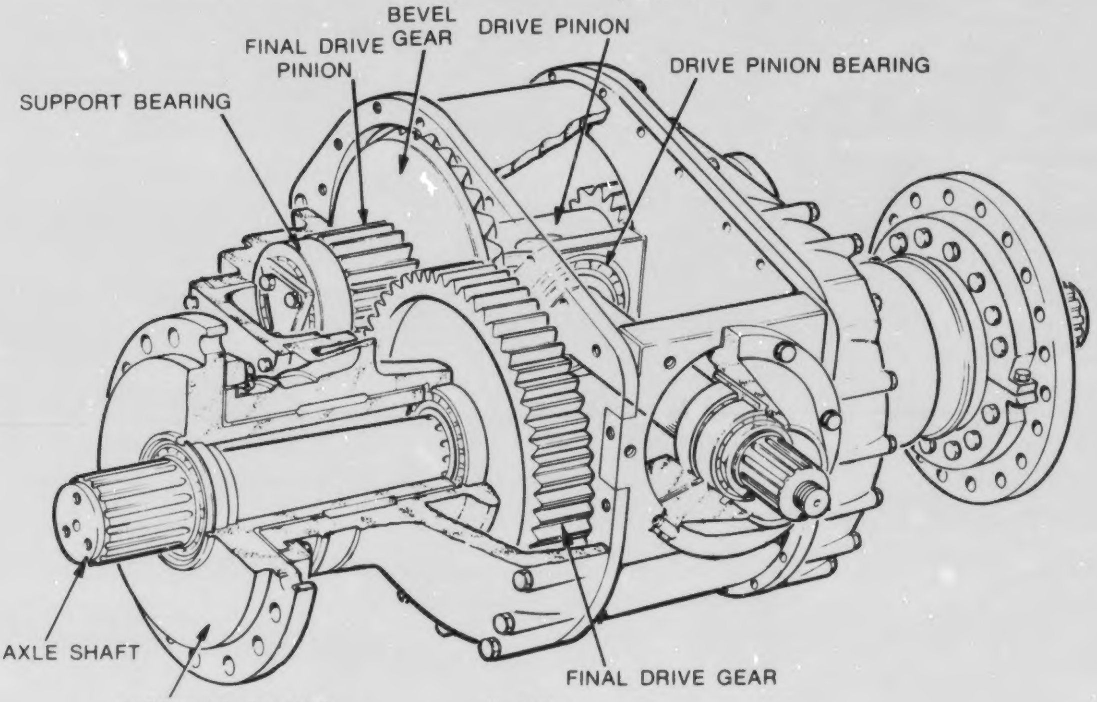
(6-347)

SINGLE REDUCTION SPUR GEAR FINAL DRIVE

X 2187

Courtesy of John Deere Ltd.

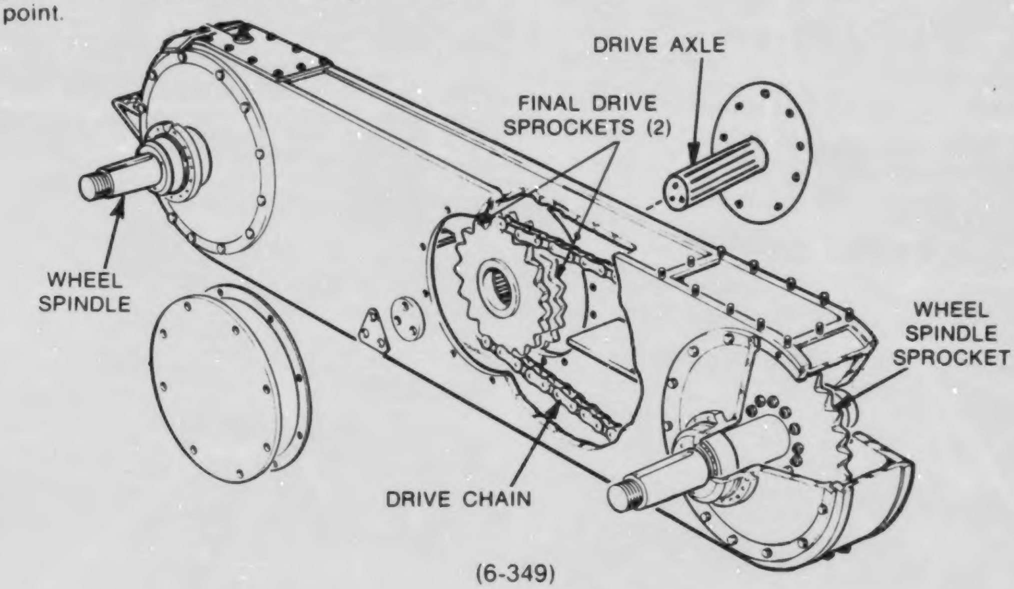
Final drive housings serve as the oil reservoir for the assembly maintaining oil at a level that supports a splash lubrication system for the gears and bearings. The housing may be separate from, or part of, the main transmission and differential case. An example of a housing assembly is shown in Figure 6-348. It has single reduction final drives located in housings on either side of the bevel gear compartment.


BEVEL GEAR
DRIVE PINION
FINAL DRIVE PINION
DRIVE PINION BEARING
SUPPORT BEARING
AXLE SHAFT
CIRCULAR FLANGE
FINAL DRIVE GEAR

(6-348)

Courtesy of Champion Road Machinery Limited

Note in Figure 6-348 that the final drive pinions are attached to the bevel gear shaft and that the large final drive gears are supported by bearings in the housings attached to the bevel gear compartment. Also note the circular flange at the outer ends of the final drive housings; this is where the tandem wheel housing assemblies, described earlier in the section on grader suspension, are bolted. A double sprocket (Figure 6-349) is splined to the final drive axle shaft which extends into the tandem housings. Power is sent from the sprockets to each wheel via separate drive chains. The tandem housing oscillates, having the final drive circular flange as its pivot point.



(6-349)

Courtesy of Champion Road Machinery Limited

SPROCKET AND CHAIN FINAL DRIVES

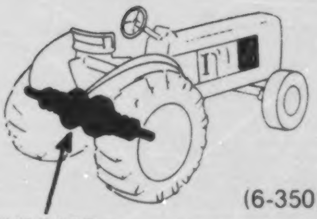
While discussing this tandem wheel assembly, it's appropriate to mention another type of final drive: the sprocket and chain. Just as different size gears can alter speed/torque ratio, so can different size sprockets. If the two sprockets on the final drive axle are the same size as the sprockets for the wheel spindle, then there is a one to one ratio and no speed reduction occurs. If, however, there is a small sprocket at the drive axle and a larger sprocket at the wheel spindle, then a reduction will occur: power train speed will be reduced and its torque increased.

The tandem wheel assembly is partially filled with oil so that the chain and sprockets run in an oil bath.

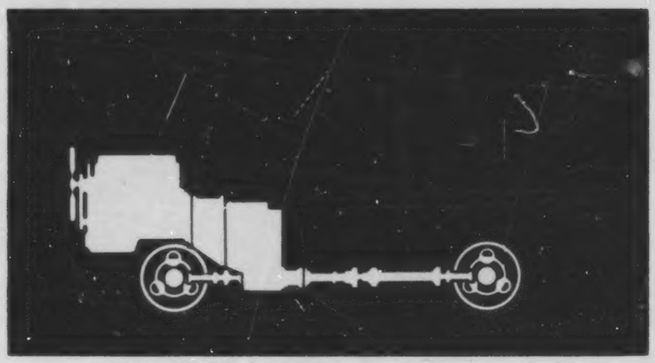
PLANETARY FINAL DRIVES

Planetary final drives are probably the most common type of final drive used on heavy duty wheel equipment today. A few examples of machines using planetary final drives are: loaders, skidders, scrapers, cranes, graders, and off-highway trucks.

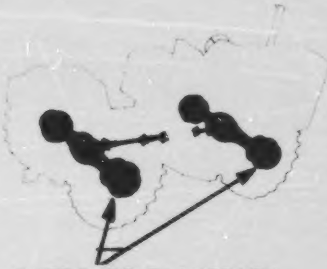
Planetaries have the advantages of (a) providing a high reduction within a compact space and (b) being strong because the load is spread over more than one gear. The operation of planetaries was described in Block 5 Power Trains. Review this section. Planetary final drives for wheel machines may be mounted inboard, next to the differential, or outboard, next to the wheel (Figures 6-350 and 6-351).


INBOARD
PLANETARY

(6-350)
Courtesy of John Deere Ltd

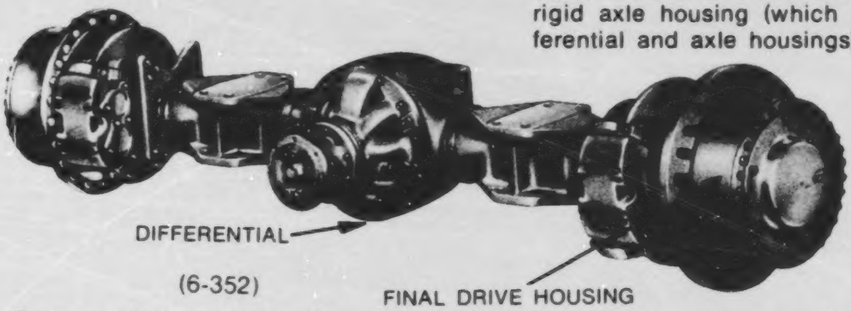


(6-351) Courtesy of Caterpillar Tractor Co


OUTBOARD PLANETARY

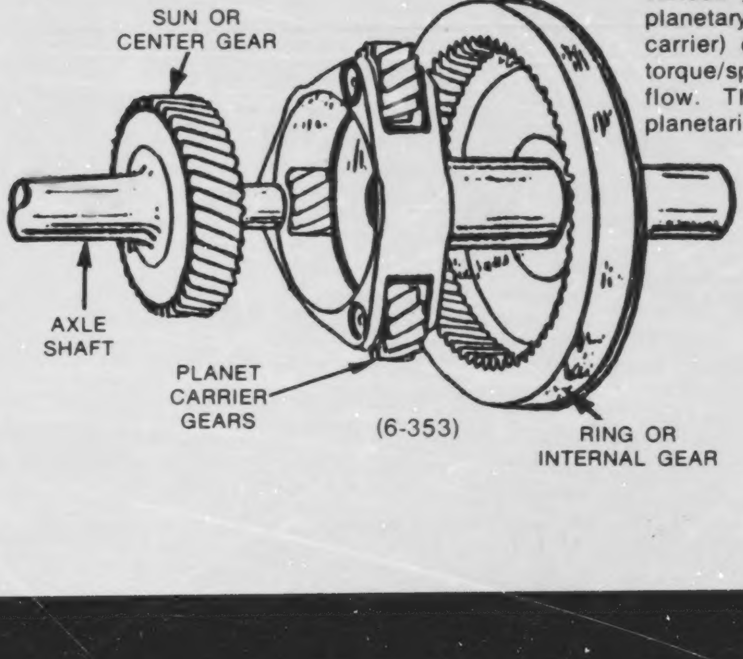
Inboard planetaries are used mainly for farm tractors, although Caterpillar uses one on their grader. Some large electric drive mine trucks also use inboard planetaries.

Outboard planetaries are the most common type of wheel final drive used today, a main reason being that they are conveniently located for servicing. Most of the necessary service on these planetaries can be performed without jacking up the unit or removing the tires. The outboard position also gives the torque increase at the wheel and so the axle shaft doesn't have to carry the increased torque. The housings for outboard planetaries are incorporated within the wheel-hub assembly and are mounted on the outer ends of the rigid axle housing (which includes the differential and axle housings) (Figure 6-352).


DIFFERENTIAL
FINAL DRIVE HOUSING

(6-352)
Courtesy of Rockwell International Automotive Operations

As you recall from the introduction to planetaries in Block 5, Power Trains, there are various possible combinations of the three planetary gears (the ring, sun, and planet carrier) each of which will give a different torque/speed ratio and direction of power flow. The combination used for wheel planetaries is (Figure 6-353):

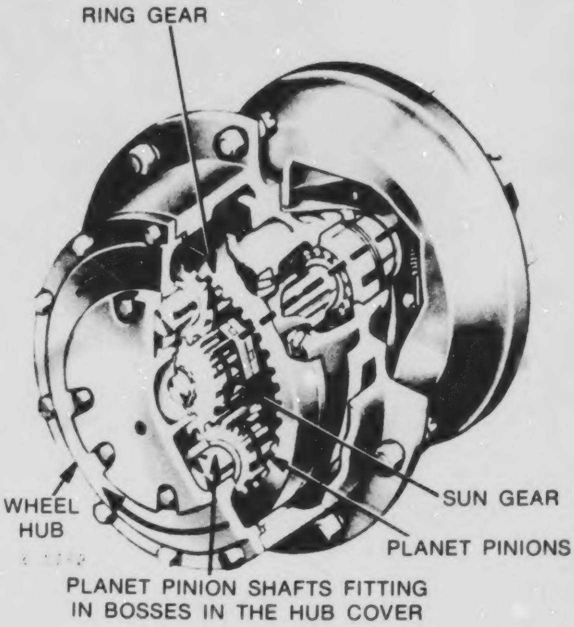

SUN OR
CENTER GEAR
AXLE
SHAFT
PLANET
CARRIER
GEARS
RING OR
INTERNAL GEAR

(6-353)

1. The ring gear is held. Usually it is splined or attached to the stationary housing.
2. The sun gear, splined to the axle shaft, is powered.
3. The carrier is driven by the sun around the inside of the stationary ring gear. Since the carrier is attached to the wheel hub, the hub and wheel assembly are driven at a reduction. Figure 6-354 shows how the carrier is attached to the hub: the ends of the planet gear shafts fit into bosses in the hub cover which is bolted to the hub. Therefore when the carrier turns, tbe hub is forced to turn. Notice in this planetary final drive how all the gears fit inside one another and hence the reason for its compactness.

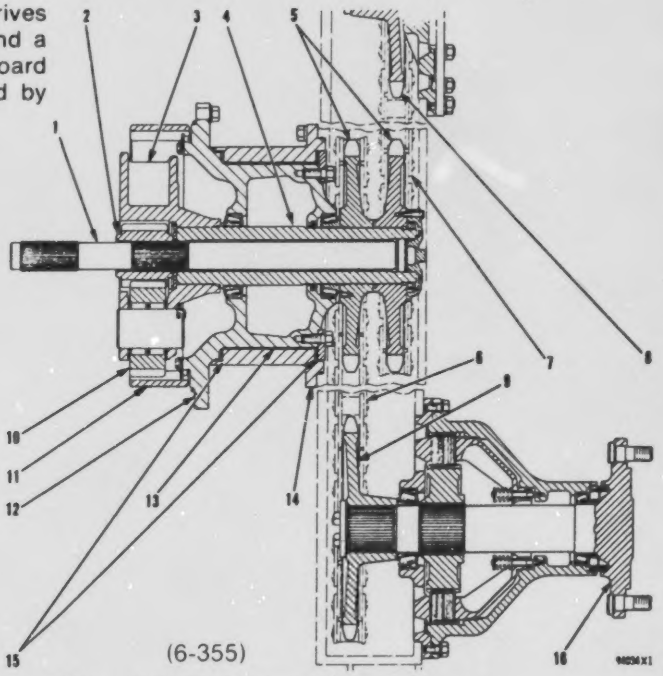
The above planetary transmits power from the planet carrier to the wheel hub. When planetaries are used on a grader, the carrier is attached to a shaft that is connected at its other end to the drive sprockets in the tandem wheel assembly (Figure 6-355).

Outboard final drives are lubricated by splash. Some wheel final drives have an oil fill plug on the outer cover which is also the oil level plug: oil is filled through this hole until it begins to flow out. Other wheel final drives have a fill plug on the outer housing and a separate level plug on the cover. Inboard planetaries are usually splash lubricated by oil from the bevel gear compartment.



(6-354)

Courtesy of John Deere Ltd.



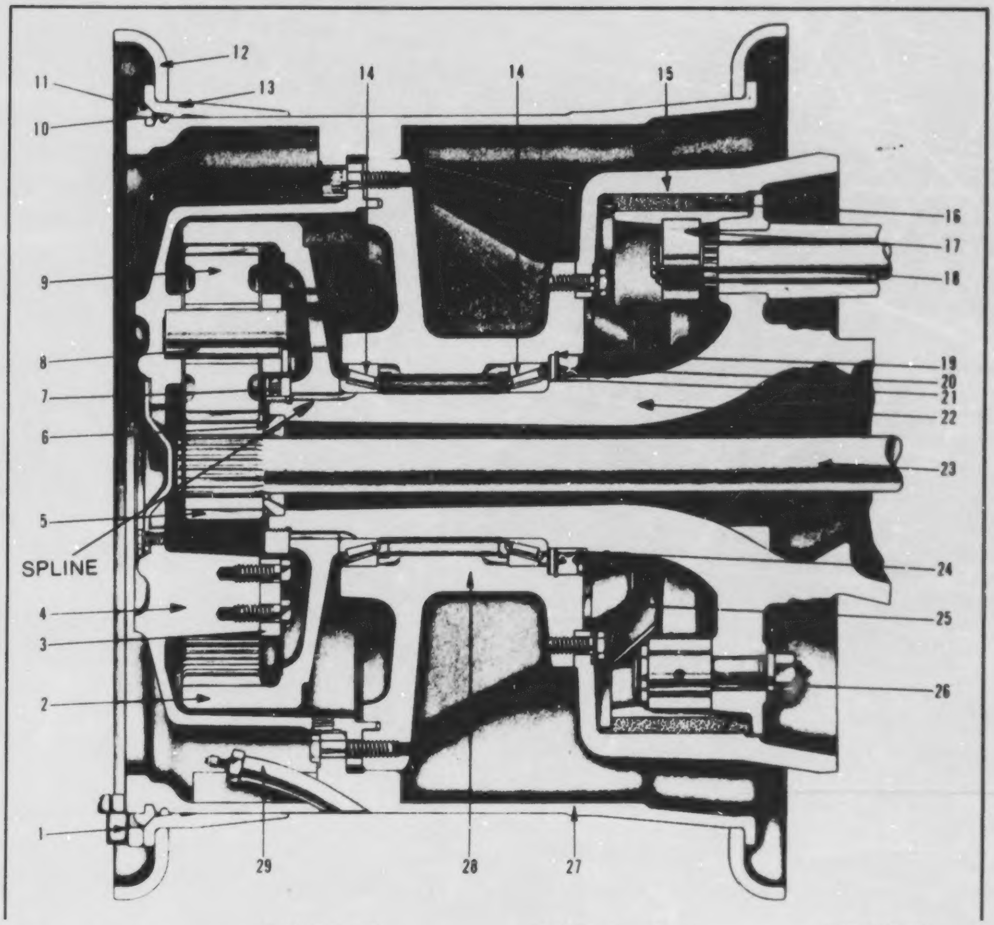
(6-355)

FINAL AND TANDEM DRIVES

1—Shaft. 2—Sun gear. 3—Carrier. 4—Outer shaft. 5—Drive sprockets. 6—Drive chain. 7—Drive chain. 8—Driven sprocket. 9—Driven sprocket. 10—Planet gear. 11—Ring gear. 12—Housing. 13—Ring. 14—Housing. 15—Thrust washers. 16—Wheel spindle.

Courtesy of Caterpillar Tractor Co

A cutaway view of an outboard planetary is shown in Figure 6-356. Note that the ring gear (2) is held by a spline on the outer end of the spindle (22). The lock nut assembly (7) holds the ring gear in place and provides the means of adjusting the wheel bearings (14). The planetary cover (4), part of the carrier, transmits the drive to the wheels. The axle shaft (23) is full floating; it transmits power and does not carry any of the vehicle's weight. The spindles support the weight, as it does in all outboard planetary wheel final drives.



1 Driver
2 Ring Gear
3 Retainer Ring
4 Planetary Cover
5 Sun Gear
6 Spacer Ring
7 Locknut Assembly

8 Pinion Pin
9 Planet Pinion
10 "O" Ring
11 Lock Ring
12 Flange
13 Bead Seat
14 Bearing Assembly

15 Brake Drum
16 Brake Shoe Assembly
17 Cam
18 Cam Shaft
19 Snap Ring
20 Seal
21 Puller Washer

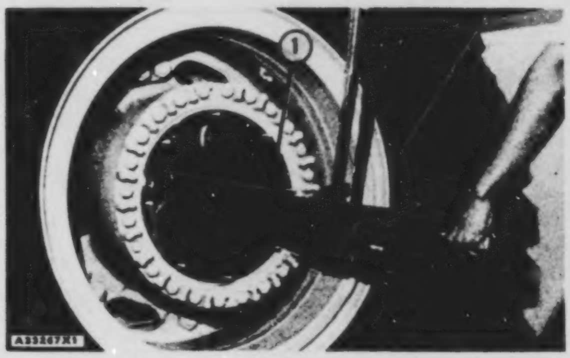
22 Spindle
23 Axle Shaft
24 Seal Bushing
25 Grease Guard
26 Anchor Pin
27 Rim
28 Wheel
29 Valve Assembly

(6-356)

Courtesy of Terex. General Motors Corporation

Towing Precautions Involving The Axle and Planetary

If a vehicle having wheel final drives is to be towed, due to a breakdown for example, the axle shaft and sun gear should be removed from each planetary assembly (Figure 6-357). Removing them will prevent possible damage to the power train components during towing. The axle shafts and sun gears can be removed easily by taking off the driving flange cover and simply sliding the axle shaft, together with the sun gear, out of each planetary assembly. Pour a small amount of oil in, and replace the driving flange covers to protect the planetary assemblies from road dust and dirt.



(6-357)

Courtesy of Caterpillar Tractor Co.

MAINTENANCE AND SERVICE REPAIR OF WHEEL MACHINE FINAL DRIVES

PREVENTIVE MAINTENANCE

DAILY, ROUTINE MAINTENANCE CHECKS

A visual inspection of the final drives should be included as part of the daily walk around check. The inspection involves checking for oil leaks and periodically (approximately every 250 hours) checking the oil level. Note that outboard planetaries and grader chain and sprocket tandem wheel assemblies have their own oil supplies, whereas inboard planetaries and spur gear final drives usually share a common oil reservoir with the differential. Always maintain final drives at the correct oil level; if the oil is down, overheating will occur and the gear will be damaged.

SCHEDULED MAINTENANCE

Scheduled Maintenance for wheel final drives includes:

1. draining the housing
2. checking for accumulation of metal chips
3. refilling with the correct type and amount of oil
4. checking for leaks when complete.

The hour interval for the oil change varies with the manufacturer, anywhere from 1000 to 2000 hours. This interval will be shorter if the machine is working in a lot of water or in heavy rain. Note that vehicles having outboard planetaries, final drives and wheel brakes will have the planetary oil changed every time the brakes are serviced because the brakes can only be reached by disassembling the final drive. Brakes will usually be serviced at 1000 to 1500 hour intervals, although this interval will depend on the severity of the work the machine is performing.

Final Drives should give many miles or hours of trouble-free service providing (1) the seals are replaced when work is done on the assembly, (2) the bearings are adjusted correctly, and (3) the oil is maintained at the correct level. However, final drives are subject to damage by shock loading, frequent direction change, and over loading.

SERVICE REPAIR OF WHEEL FINAL DRIVES

Indications that final drives need repair are:

1. Accumulation of metal chips found in the final drive oil when changing it.
2. A leaking final drive that requires frequent topping up.
3. Unusual noises in the wheel assembly.

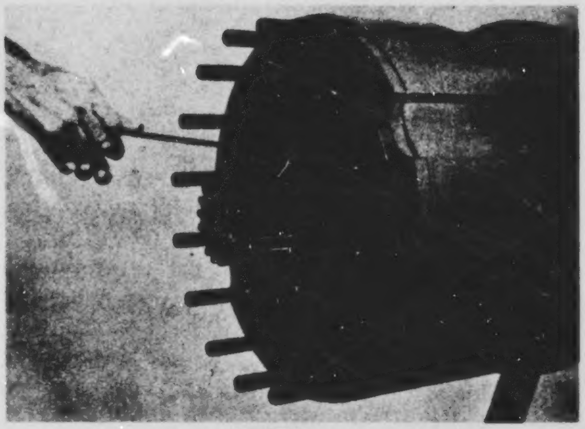
Not heeding these warning signs could lead to complete failure of the unit.

Procedures required to gain access to the different types of final drives — single reduction spur gear, sprocket and chain, and planetary — vary, but there are some similarities such as cleaning the assembly, draining its oil and removing wheels. Outboard planetaries are the most common type of wheel final drive, and so points about its removal and repair are given below:

1. Always clean the housing area where the work is to be done. Use a steam cleaner or a high pressure washer. If this equipment is not available, wash by hand.
2. In preparing to remove planetaries, block and jack the machine so that the tires just clear the floor. If the machine has articulated steering install the steering safety rod.
3. Although planetaries may be disassembled without taking off the wheels, it is usually much more convenient to do so. Follow safety practices for removing wheels discussed earlier.
4. **When draining the oil, removal of the level plug (if applicable) will vent the final drive and thus aid in the draining.**
5. **Disassembly of the planetary is fairly straight forward. If the hub is not going to be removed, support it with a sling and overhead crane or a floor jack. It is a good practice to remove the hub, though, so that the bearings can be cleaned, inspected, repacked and the seal replaced. Figure 6-358 shows some of the dismantling procedures of a typical outboard planetary.**

(6-358) REMOVE PLANET COVER

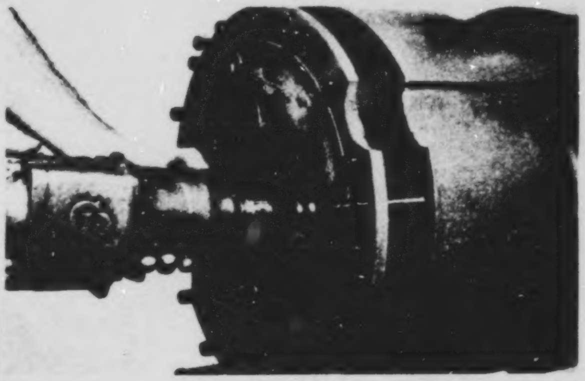
Courtesy of Clarke Equipment Company



(6-358)

USING A HEAVY WIRE HOOK, PULL AXLE SHAFT AND SUN GEAR OUT OF WHEEL END

Courtesy of Clarke Equipment Company



(6-358)

USING THREADED BOLTS IN THE PULL HOLES PROVIDED, EVENLY REMOVE PLANET CARRIER ASSEMBLY. USE CAUTION AS NOT TO RUN CARRIER OFF STUDS BEFORE A CHAIN SUPPORT IS USED.

Courtesy of Clarke Equipment Company

6. Once disassembled, all final drive parts such as gear teeth, shafts, thrust washers, splines should be cleaned and inspected for wear and damage. (Refer to the section on types of gear wear in Crawler Final Drives.) Replace all badly worn or damaged parts saving the old parts for comparison with the new before installing the new ones.

Good Installation Practices For Final Drives

1. Pre-lub all gear shafts and thrust washers.
2. Replace all gaskets and O-rings.

3. Use the correct tool for installing seals. When installing a new lip-type oil seal, make sure it is flexible or pliable in the area where the seal fits around the shaft. Also, lubricate the lip before installing the hub.

4. Follow from the service manual the correct procedures for preloading the bearings. A common example of preloading the wheel bearings (new and used) on a machine having an outboard planetary is given below:

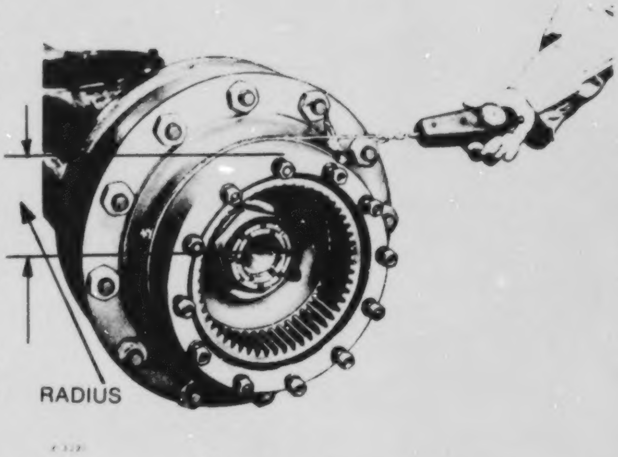
   (a) Lubricate both bearings with gear oil or grease as specified in the service manual.

   (b) While turning the planetary housing, tighten the wheel bearing nut to 400 feet-pounds. Turn the planetary housing in both directions to correctly seat the wheel bearings.

   (c) Loosen the wheel bearing nut one quarter turn.

   (d) Connect at least ten feet of cord to a pound pull scale. Connect the loose end of the cord to one of the wheel nut studs and wrap the cord around the planetary housing as illustrated in Figure 6-359.

   (e) Pull the scale on a horizontal line by backing away from the machine. Read the scale as the planetary housing is turning. The scale indication must be 9 to 13 pounds. Do this step two more times to get an accurate indication of the force needed to turn the planetary housing. DO NOT read the scale as the planetary housing starts to turn. If the force needed to keep the planetary housing turning is not 9 to 13 pounds, tighten or loosen the wheel bearing nut accordingly and test again.



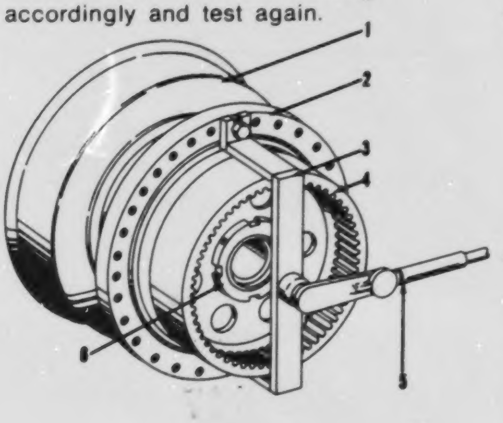
(6-359) CHECKING BEARING PRELOAD WITH PULL SCALE

Courtesy of John Deere Ltd.

Note that in this example the preload is given in straight pounds pull. Often the preload will be given in inch-pounds which is found by multiplying the radius (distance from the center of the drive shaft to a point on the circumference from which the cord is pulled, (Figure 6-359) by the reading on the pound scale. For example: Assume the radius is 7 inches and the reading on the scale is 9 pounds. Multiply 7 inches by 9 pounds and to get 63 inches-pounds of rolling torque.

Preload can also be given in feet-pounds. To change the 63 inches-pounds from the example to feet-pounds simply divide the 63 by 12 to get 5.25 feet-pounds of preload.

Another method of checking bearing preload is to use a torque wrench with a special tool or adapter (Figure 6-360). The adapter can be easily made up. This method gives a direct reading on the wrench.



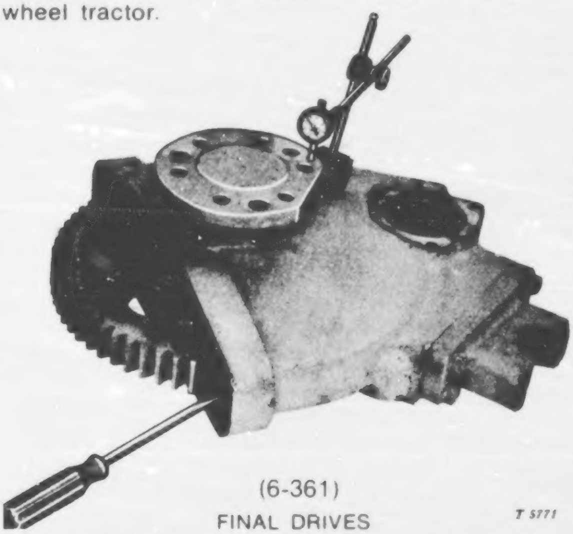
(6-360)

1—Brake drum. 2—Wheel. 3—Special tool. 4—Ring gear. 5—Torque wrench. 6—Locknut.

Courtesy of Terex. General Motors Corporation

Adjusting Axle End play

Some types of drive assemblies call for a slight amount of end play. This means that the shaft, when properly adjusted, must be free to move endways within the limits specified. The end movement in most cases is between 0.001 and 0.010 inches. To obtain the proper end play, shims or an adjusting nut are provided. Measure the end play with a dial indicator. As shown in Figure 6-361: this is a single reduction final drive assembly for a small wheel tractor.



(6-361)
FINAL DRIVES
CHECKING FINAL DRIVE SHAFT END PLAY WITH A DIAL INDICATOR
Courtesy of John Deere Ltd.

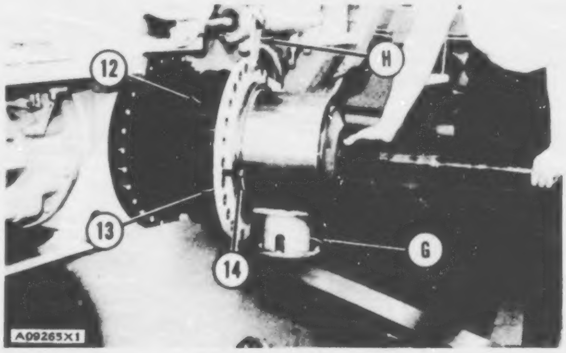
Removing and Installing Grader Tandem Housings

The procedures for removing and installing tandem housings vary from one grader to another (see service manual for specific procedures), but there are some steps that are common to most graders:

1. Thoroughly clean the tandem housings, including the wheel spindles and oscillation or pivot point, before starting disassembly. The cleaning, due to the size of the job, is time consuming to do by hand, and should be done with a steam cleaner or high pressure washer.
2. Jack and block the machine so that the wheels are free of the floor. Then remove the wheels.
3. Drain the oil from the housing.
4. Remove the drive chains.
5. Attach an overhead crane or similar type of lifting equipment to the housing. Remove the housing attaching bolts and lift the housing clear of the machine. Note that the center drive sprocket may have to be removed before the housing can be removed and the brake lines disconnected.
6. Disassemble the spindles. Clean and inspect the sprockets, drive chains, splines, bearings and seals for damage and wear. Make a list of the parts required.
7. Reassemble the tandem in the reverse order, following recommended torques and adjustments given in the service manual.
8. Refill the housing with the correct type and amount of oil. Check for leaks.

Removing The Final Drives

To remove a final drive once the tandem housing is off may require, on some machines, removing the complete differential assembly. However, on other machines the final drives are accessible from the outside as is shown in Figure 6-362. Here the final drive is being rolled from the machine on a wheel jack. Disassemble the final drive and clean and inspect the parts, replacing any that are worn or damaged.



(6-362)
Courtesy of Caterpillar Tractor Co.

QUESTIONS — WHEEL FINAL DRIVES

1. Wheel final drives:
   - (a) decrease speed and increase torque.
   - (b) increase speed and decrease torque.
   - (c) decrease speed and decrease torque.
   - (d) increase speed and increase torque.
2. List the three major types of final drives used on wheel equipment.
3. What is the advantage of having the final drive out at the wheel assembly rather than next to the differential?
4. How can the sprockets and chains in a grader tandem housing give a reduction?
5. What is the most common type of final drive used on wheel machines? Give at least two examples of machines using these final drives.
6. On a planetary wheel final drive, how does the carrier gear transmit power to the hub?
7. Wheel final drives are lubricated by:
   - (a) pressure feed.
   - (b) splash feed.
   - (c) combination of splash and pressure feed.
   - (d) pre-lubricating all the parts with grease on assembly.
8. If a machine equipped with planetary wheel final drives has to be towed:
   - (a) the planet carrier should be removed.
   - (b) the sun gear should be removed.
   - (c) the sun gear and axle shaft should be removed, and the cover replaced.
   - (d) the ring gear should be removed.
9. Final drives are subject to damage by what three common causes?
10. List three signs that would indicate wheel final drives need repair.
11. True or False? The complete wheel and hub assembly must be removed to disassemble a planetary final drive.
12. To check the preload on wheel bearings using the spring scale method:
    - (a) multiply the pounds pull on the scale times the circumference of the hub.
    - (b) multiply the pounds pull times the diameter of the hub.
    - (c) multiply the pounds pull times the radius of the hub.
    - (d) multiply the pounds pull times the number of wraps of cord around the hub.
13. True or False? Some graders have two final drive reductions: one before the tandem housing and one within the tandem housing.
14. Does the drive sprocket in a tandem housing have to be taken off before the housing can be removed?

ANSWERS — WHEEL FINAL DRIVES

1. (a) decrease speed and increase torque.
2. Single reduction spur gear.

   Planetary.

   Sprocket and chain.
3. Outboard final drives are:
   - conventiently located for servicing.
   - positioned so that the drive axle shaft doesn't have to carry the increased torque.
4. If the wheel spindle sprocket is larger than the drive sprocket, a reduction is achieved.
5. Planetary final drives: loaders, skidders, scrapers.
6. The ends of the shafts for the carrier planet pinion gears fit into bosses in the hub cover causing the hub to turn.
7. (b) Splash feed.
8. (c) The sun gear and axle shaft should be removed and the cover replaced.
9. — Shock-loading.

   — Frequent direction changes.

   — Overloading.
10. — Accumulation of metal chips in the final drive oil.

    — Leaks requiring frequent topping up of final drive oil.

    — Unusual noises in the assembly.
11. False.
12. (c) Multiply the pounds pull times the radius of the hub.
13. True.
14. On some machines, but not on others.

TASKS — WHEEL MACHINE FINAL DRIVES

DAILY, ROUTINE MAINTENANCE CHECK

Check a wheel machine's final drives for leaks at seals and gasket joints and for any other visible damage. Report any major service repair needed.

SCHEDULED MAINTENANCE CHECK

Scheduled maintenance procedures from the service manual for a wheel machine's final drives include:

1. Drain the housing, inspect the oil for metal chips and signs of moisture. Report any chips or moisture detected and make recommendations for needed repairs.
2. Replace the drain plug and refill the housing with the correct type and amount of lubricant.

SERVICE REPAIR

1. Using the correct jacking and blocking procedures (on articulated machines install the steering safety rod), raise a wheel machine with final drives and block it securely at a height that allows the wheel and final drive assembly to be safely removed.
2. Using the correct tools, lifting equipment and procedures outlined in the service manual:
    (a) drain the final drive housing.
    (b) remove the wheel and steam clean the final drive assembly.
    (c) disassemble, inspect the gears, bearings, seals (sprockets and chains if grader). Write a parts list. Make the necessary repairs and replacements.
    (d) prelubricate the final drive parts, reassemble and adjust the bearings.
    (e) install the wheel, tightening the nuts in the correct sequence.
    (f) fill the drive line housing with the correct type and amount of oil, and ensure there are no leaks.

BLOCK

6

Wheel Machine Steering and Front Suspension

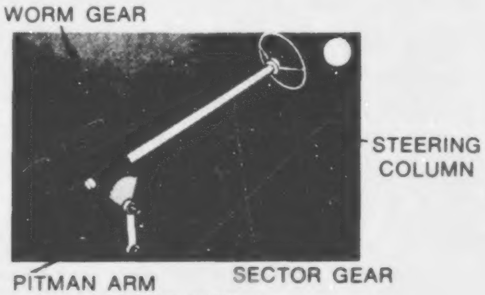
STEERING PRINCIPLES

Not all wheel vehicles use their front wheels for turning, e.g., some loaders have back wheels that turn. Other machines such as skidders, scrapers, wheel dozers and loaders have articulated steering. Although there are differences in the way that wheel machines are steered, they do share some common steering principles.

HOW WHEELS TURN

To illustrate how wheels turn, a basic manual steering system is described below.

The steering wheel is attached to the end of the steering column or shaft. At the lower end of the shaft is a worm gear that rotates as the steering wheel is turned (Figure 6-363). The worm gear meshes with a sector gear which is shaped like a slice of pie. The sector gear need not be circular because it only rotates a few degrees (approximately 30°) in each direction. The sector gear has a lower extension called a steering arm. This arm is sometimes referred to as a Pitman arm (Figure 6-363).

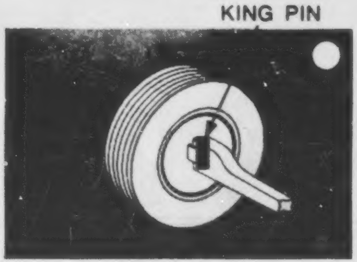


(6-363)

Courtesy of Caterpillar Tractor Co.

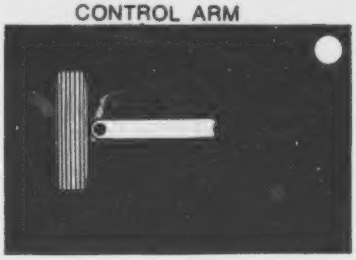
Looking at these steering parts in operation, the steering wheel turns the steering column and worm gear. The worm gear moves the sector gear, which pivots at the center, causing the steering arm to move back and forth. Thus rotary motion at the steering wheel is transformed into linear motion at the steering arm.

Move now from the steering box section of the steering system to the wheels. The front wheels are attached to the axle by a pivot pin (king pin) that acts as a hinge allowing each wheel to turn (Figure 6-364). To control wheel movement, a short arm, called a steering control arm, is attached to the wheel (Figure 6-365). When the steering arm is moved the wheel turns.



(6-364)

Courtesy of Caterpillar Tractor Co.

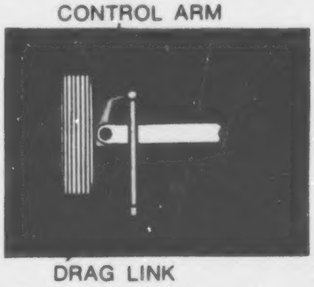


(6-365)

Courtesy of Caterpillar Tractor Co.

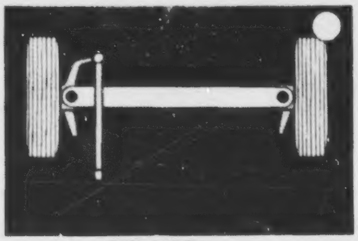
The steering part that connects the wheels to the steering box is called a drag link (Figure 6-366). The drag link is attached at one end to the wheel control arm and at the other to the Pitman arm. Movement of the steering wheel can now be transferred to the wheel.

One more part is needed to complete the steering system. The steering mechanisms, as shown, are connected to only one wheel, the left front. Some method is needed to synchronize its movement with that of the right front wheel. A tie rod (or cross tube) does this. It is connected to an extension of the control arm and travels across to an arm on the other wheel (Figure 6-367). When the left wheel is turned, the tie rod makes the right wheel follow. A completed basic manual steering system is shown in Figure 6-368.



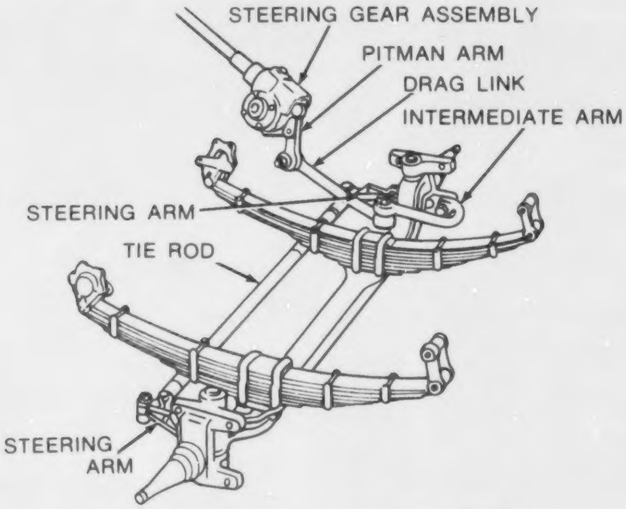
(6-366)

Courtesy of Caterpillar Tractor Co.



TIE ROD
(6-367)
Courtesy of Caterpillar Tractor Co.

A point to note about this steering system is that the worm gear can turn the sector gear, but the sector can't turn the worm. This one way relationship is made possible by the gear reduction between the worm and the sector. It is an important feature, because otherwise, if a wheel struck a curb or a stone, a reverse steering would be set in motion that could jerk the steering wheel from the driver's hands.



(6-368) SOLID AXLE STEERING LINKAGE
Courtesy of Ford Motor Company

TYPES OF WHEEL STEERING SYSTEMS

1. Manual Steering
2. Power Steering
   - — power-assist
   - — full power
   - — hydrostatic
3. Emergency steering

MANUAL STEERING SYSTEMS

A basic manual steering system has been described above in the section on how wheels turn. The material here takes a closer look at the following manual steering parts.

Manual Steering Gears
- — worm and roller
- — recirculating ball
- — cam and lever

Front Axles and Suspension
- — spring hanger brackets
- — shackles, pins, bushings
- — springs, U-bolts
- — shock absorbers
- — steering axle
- — king pins
- — steering knuckle and bushings

Steering linkage
- — steering spindle arms
- — tie rods, tie rod ends

Grader Steering Parts

MANUAL STEERING GEARS

The function of manual steering gears is to:

1. Change the rotary motion at the steering wheel to linear movement at the tie rod to steer the wheels.
2. Steer a vehicle with a minimum of effort. A small force at the steering wheel must turn a heavy mass at the front axle. This advantage is gained by the gear ratios in the steering box which can range from about 12:1 to 28:1, and even higher.
3. Dissipate road shock. The mechanical advantage of the high gear ratio helps cushion shocks.

There are three types of manual steering gears currently found in the heavy duty field:

- — worm and roller
- — recirculating ball
- — cam and lever

Another manual gear, the worm and sector, was used in the past but is seldom seen today.

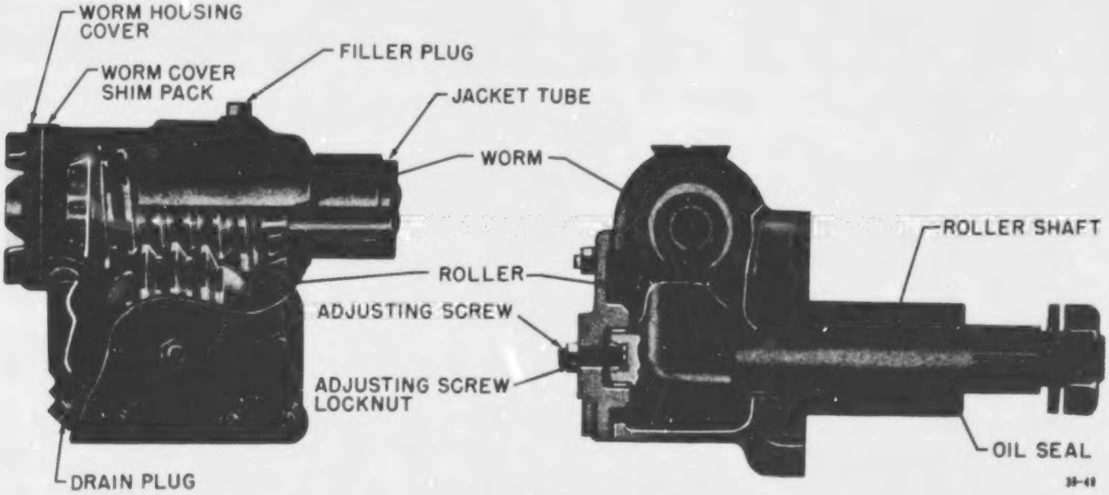
Worm and Roller Gear

This steering gear consists of an hourglass-shaped worm gear meshed with an offset, three-tooth roller gear. The roller gear is part of a roller shaft (Figure 6-369).

The worm gear is supported by tapered roller bearings; one bearing cup is pressed into the steering gear housing, while the other cup is slip fitted to permit the bearings to be preloaded. The preload adjustment is made by a shim pack located between the steering gear housing and the worm cover. The roller shaft is supported by needle bearings. Roller shaft end play is regulated by an adjusting screw threaded into the roller shaft cover.

The worm and roller gear operates as follows: the worm is connected to the steering wheel through either a coupling just outside the steering gear box or by a continuous shaft that goes directly to the wheel. The roller shaft is splined to the Pitman arm. When the steering wheel is rotated, the worm gear "rolls" the roller gear causing the roller shaft to rotate. The roller shaft, in turn, sets the Pitman arm and steering linkage in motion to steer the vehicle.

Worm and roller manual steering gears are used in a wide variety of vehicles from trucks and buses to industrial machines. The same basic design has been used for many years. The gear is simple, yet strong, and gives a fairly low-friction operation.



(6-369)
WORM AND ROLLER GEAR

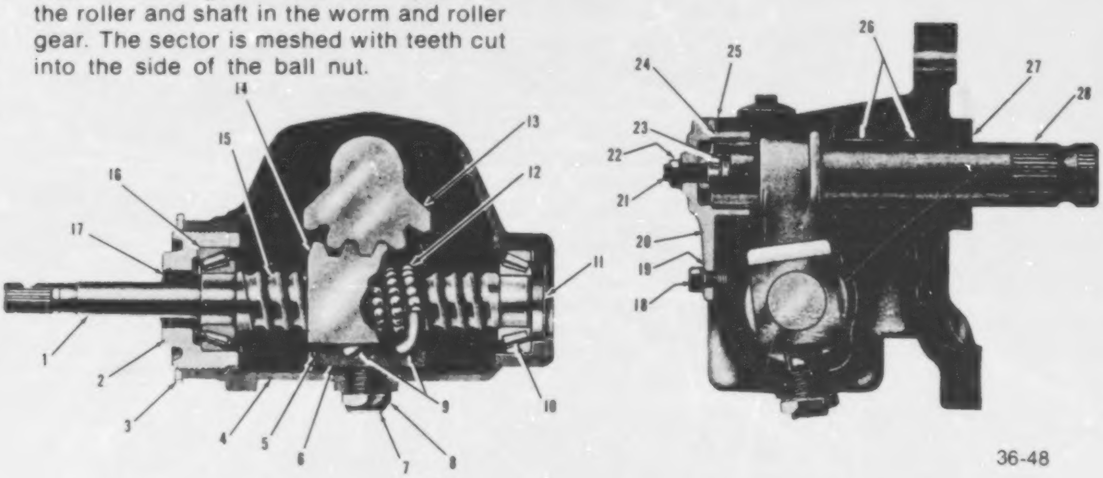
Courtesy of Mack Truck Limited

Recirculating Ball Steering Gear

A recirculating ball steering gear:

1. Uses a straight worm as opposed to the hourglass-shaped worm of the worm and roller steering gear.
2. Has a ball nut that is supported on the worm by a number of steel balls that act as bearings, minimizing friction between the ball nut and worm. During movement of the ball nut on the worm the steel balls continuously recirculate from one end of the nut to the other through a ball return guide (9, in Figure 6-370).
3. Uses a sector gear and shaft in place of the roller and shaft in the worm and roller gear. The sector is meshed with teeth cut into the side of the ball nut.

Provision is made to externally adjust the worm shaft bearings and the sector shaft. The worm shaft (1) is mounted between two tapered roller bearings (10, 16). Preload on these bearings is adjusted by means of a thrust bearing adjuster (2) which is threaded into the steering gear housing (4). The sector shaft (28) is mounted in bushings in the gear housing and the side cover (20). Lash between the sector gear and ball nut is controlled by a lash adjuster (21), located in the side cover. End play of the sector shaft is controlled by a shim (23) under the head of the lash adjuster.



36-48

1	Worm Shaft
2	Thrust Bearing Adjuster
3	Adjuster Locknut
4	Steering Gear Housing
5	Clamp Retainer Screw
6	Ball Guide Clamp
7	Back-up Adjuster
8	Back-up Adjuster Locknut
9	Ball Guide
10	Worm Thrust Bearing, Lower
11	Expansion Plug
12	Worm Balls
13	Sector Gear
14	Ball Nut
15	Worm (Integral with Shaft)
16	Worm Thrust Bearing, Upper
17	Worm Shaft Oil Seal
18	Side Cover Bolt
19	Lockwasher
20	Side Cover
21	Lash Adjuster
22	Lash Adjuster Locknut
23	Lash Adjuster Shim
24	Side Cover Bushing
25	Side Cover Gasket
26	Housing Bushing
27	Sector Shaft Oil Seal
28	Sector Shaft

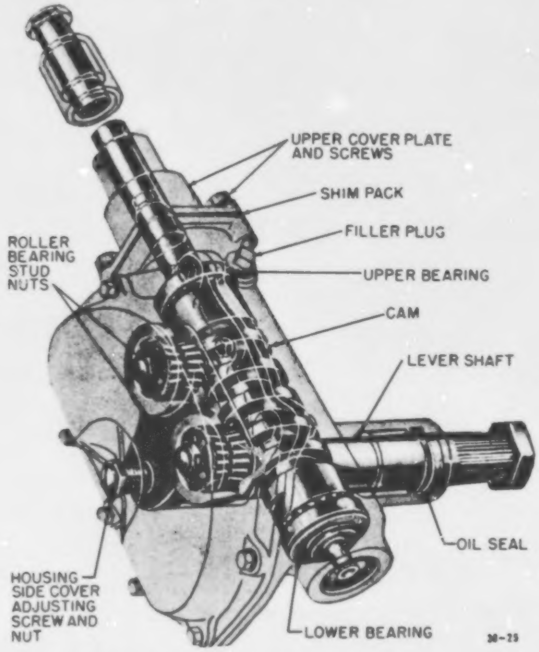
(6-370)

Courtesy of Mack Truck Limited

Recirculating ball steering boxes are used on a wide range of vehicles. However, they're not used on heavier vehicles as much as worm and roller steering gears. Recirculating ball steering gears have a low-friction operation and a simple design which makes them very adaptable to power-assisted steering.

Cam and Lever Steering Gear

The cam and lever steering gear (Figure 6-371) has a tapered stud (single lever design), or two tapered studs (twin lever design), which engage helical grooves in a cylindrical cam. (The cam is similar to the worm used in the recirculating ball steering gear). The studs are attached to an L-shaped lever arm that replaces the sector gear and shaft or roller gear and shaft used in the two previously described steering gears.


UPPER COVER PLATE AND SCREWS
SHIM PACK
FILLER PLUG
ROLLER BEARING STUD NUTS
UPPER BEARING
CAM
LEVER SHAFT
OIL SEAL
HOUSING SIDE COVER ADJUSTING SCREW AND NUT
LOWER BEARING

(6-371) PHANTOM VIEW OF SG 42 STEERING GEAR
Courtesy of Mack Truck Limited

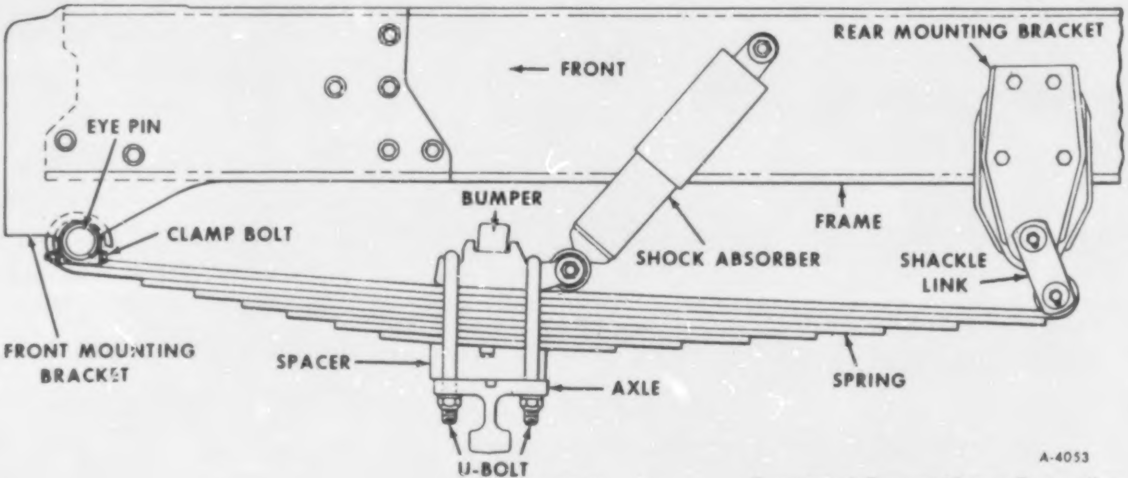
When the steering wheel is turned, the cam turns. The lever shaft studs, which are engaged in the cam groove, follow the groove and cause the lever shaft to rotate. The rotating lever shaft sets the Pitman arm and steering linkage in motion to steer the vehicle.

The cam is mounted on ball bearings and the tapered studs are mounted on roller bearings. Cam bearing preload is adjusted by a shim pack between the upper cover and the housing. End play of the lever shaft is controlled by an adjusting screw mounted in the side cover.

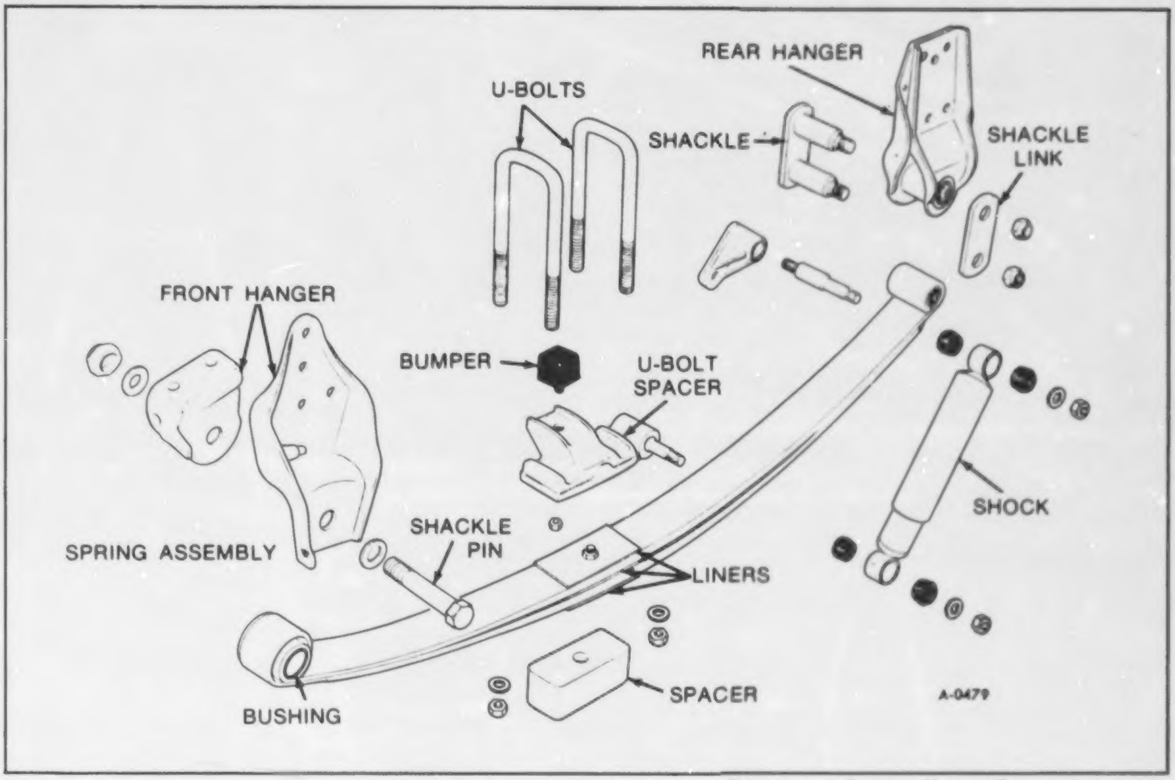
The cam and lever steering gear made by Ross is very common in the heavy duty field. A single lever model is made for smaller vehicles and a twin lever for larger ones. A cam and lever gear is often used with power-assist linkage steering, in which case the power-assist control valve will usually be in the same location as the upper cover plate. Rotary movement of the cam and subsequent end thrust created by the lever shaft moves the control valve to provide the power-assist.

FRONT SUSPENSION AND FRONT AXLES

Front suspension and front axles are an integral part of steering. Figure 6-372 shows an assembled and a disassembled view of a typical front suspension system. Suspension components are discussed below:


FRONT
REAR MOUNTING BRACKET
EYE PIN
CLAMP BOLT
BUMPER
FRAME
SHOCK ABSORBER
SHACKLE LINK
FRONT MOUNTING BRACKET
SPACER
AXLE
SPRING
U-BOLT
A-4053

(6-372)
Courtesy of General Motors Corporation



(6-372) Courtesy of General Motors Corporation

Spring Hanger Brackets

Front and rear mountings for the springs. Usually they are made of cast steel and are bolted or riveted to the frame.

Shackles

When a spring bends, the distance between the two spring eyes changes. If both ends of the spring were fastened rigidly to the frame, the spring would not be able to bend. To permit the spring to flex, only one end is attached rigidly to the frame while the other end is attached to a swinging support called a shackle. The shackle consists of two plates called shackle links and two shackle pins (described below). One of the shackle pins fits through holes in the link ends and into the spring hanger, while the other shackle pin fits through holes in the opposite end of the links and through the spring eye. This assembly of pins and links forms the swinging support. When a load is put on the spring, the shackle lets the spring swing out and thus flex. Usually the shackle is at the rear of the spring as in Figure 6-372.

Shackle Pins

The pins that attach the front and rear of the spring to the hangers are called shackle pins. The hardened steel shackle pins are the pivot point for the spring as it flexes. Lubricated shackle pins are drilled lengthwise and crosswise to distribute grease between the pin and bushings.

Shackle Bushings

Shackle bushings are installed in the eyes of the spring, (front and rear) and in the spring hangers. As the spring flexes, the eye of the spring turns slightly with respect to the spring hanger. The shackle pins and bushings must permit this movement. Most heavy duty shackle pins are drilled part way down their length and across their diameter, and have a grease fitting to lubricate the pins and bushings. Automobiles and light duty trucks generally use a pin and bushing arrangement that does not require lubrication. An automotive bushing is made of an inner and outer steel shell with a bonded rubber bushing between the two. As the spring flexes the rubber lets the spring eye turn slightly in relation to the hanger. Since there is no metal across metal movement, no lubrication is needed. Another function of the rubber center of this bushing is to help dampen suspension noise.

Springs

Heavy duty front suspension springs are generally semi-elliptical, having multiple leaves of graduated lengths. The width, thickness and number of leaves, and the overall length of the spring, are determined by the type of vehicle the springs are used on. The leaves are drilled at their centers and are held together by a center bolt. The head of the center bolt is round and fits into a corresponding hole in the axle. The bolt thus acts as a dowel holding the axle square with the frame.

Clips are placed at intervals along the spring leaves to keep the leaves in line. Often the second leaf will have its end rolled around the eyes of the main leaf to provide additional support.

U-Bolts

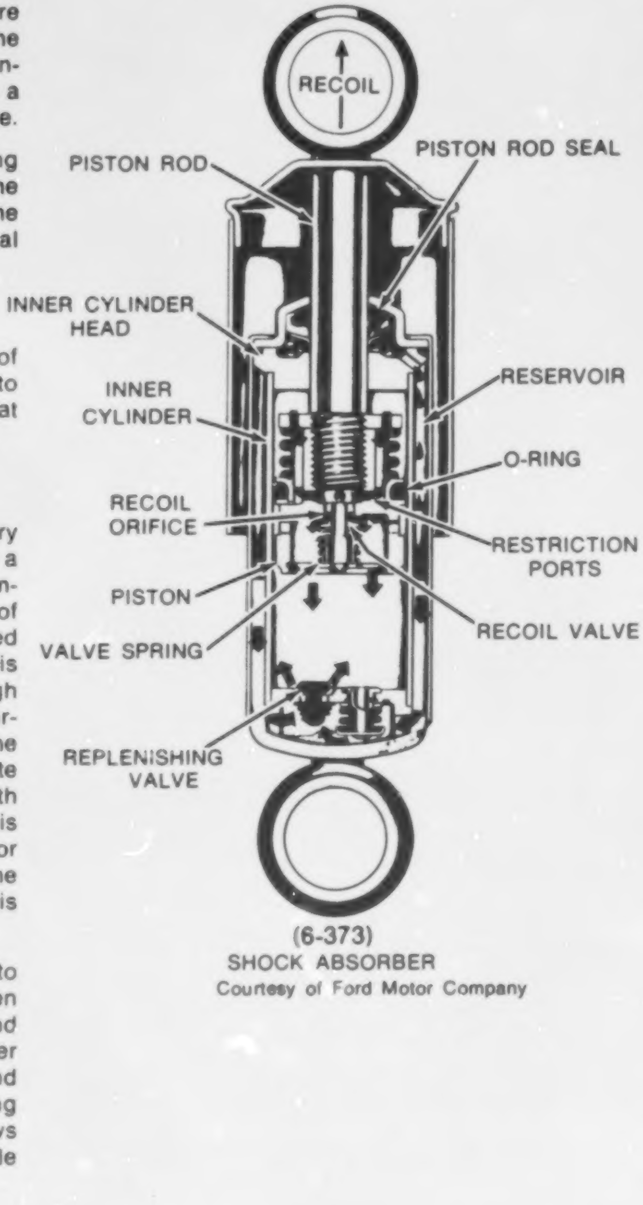
U-bolts attach the springs to the axle. Made of good grade steel, they are bent, U-shaped, to the width of the springs and are threaded at each end.

Shock Absorbers

Springs alone cannot provide a satisfactory ride and good steering control. When a vehicle is stationary, the springs are compressed to a certain degree by the weight of the vehicle. This initial compression is called the spring's rest position. When the vehicle is in motion and a wheel passes over rough ground, the spring is forced to compress further. After the vehicle has passed over the bump the spring rebounds in the opposite direction, and then oscillates back and forth until it stops at its rest position. This oscillating spring action makes for poor handling and riding characteristics, and some way has to be found to limit it. The solution is a shock absorber.

One end of a shock absorber is attached to the frame and the other end to the axle. When a wheel goes over a bump and the spring (and the axle) start to oscillate, the shock absorber picks up the oscillation from the axle and counteracts it. By lengthening and shortening with a counteracting force, the absorber slows down and limits the amount of spring and axle oscillation.

A number of different types of shock absorbers have been made in the past, but the hydraulic shock (Figure 6-373) is the only one in common use today. It is referred to as a direct-acting, telescoping shock absorber. Shock absorbers are made in various sizes and strengths.



(6-373)
SHOCK ABSORBER
Courtesy of Ford Motor Company

Shock absorbers basically consist of an outer reservoir, an inner working cylinder, and a piston and rod. The rod, attached to the piston, extends through a seal at the top of the unit and acts as the upper mount. The cylinder is filled with oil and as the rod extends and contracts the oil is forced to transfer from one side of the piston to the other through restricted ports in the piston. It is this movement of fluid through restricted ports that causes the dragging action on spring oscillation.

A compression valve and replenishing valve located in the bottom of the shock absorber connect the working cylinder and the reservoir. The compression valve relieves pressure during compression and the replenishing valve replenishes the oil in the cylinder during extension. The piston rod seal wipes the rod of excess oil during extension and returns it to the reservoir. A shield, generally attached to the outer end of the piston rod, extends down over the main cylinder and protects the rod and unit against rock damage.

There are various ways of mounting shocks; the most common for heavy duty work is by large round eyes at either end of the shock absorber. Two tapered rubber bushings are installed in each eye and fit over the mounting bolt. A nut and washer then holds the shock to the mounting bolt. The rubber bushings give some flexibility and dampen suspension noise.

Maintenance of shock absorbers includes replacing rubber mounting bushings, and tightening loose mounting bolts. Shock absorbers are not adjustable, nor are they repairable. If one fails the complete unit must be replaced.

STEERING AXLE

The steering axle assembly consists of the following parts:

Axle center — I-Beam or Tubular construction

Steering knucle pins (king pins)

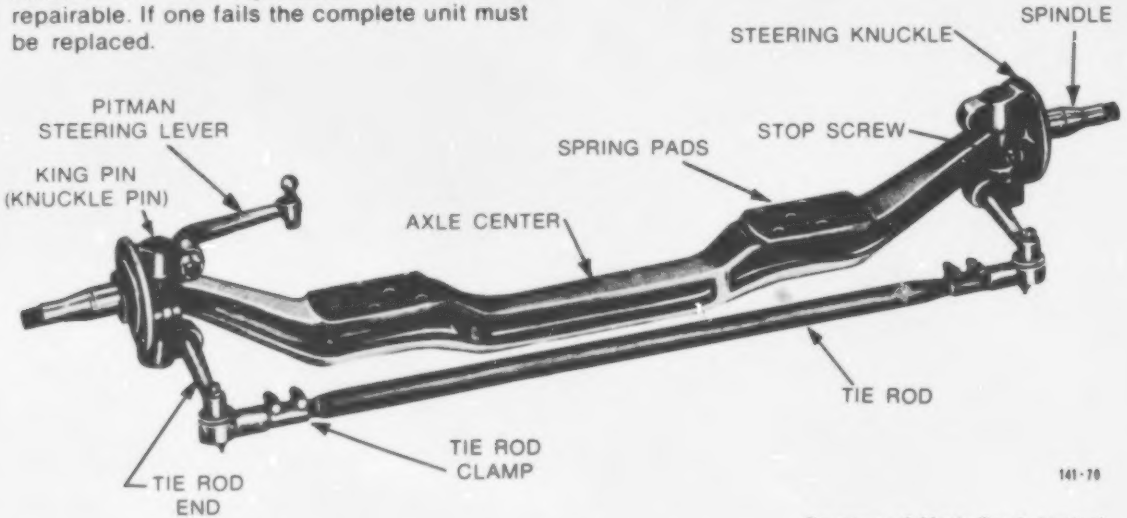
Steering knuckle (spindle assembly)

Steering linkage including:

- — steering arms
- — drag link
- — Pitman arm
- — tie rod
- — tie rod ends

Axle Center

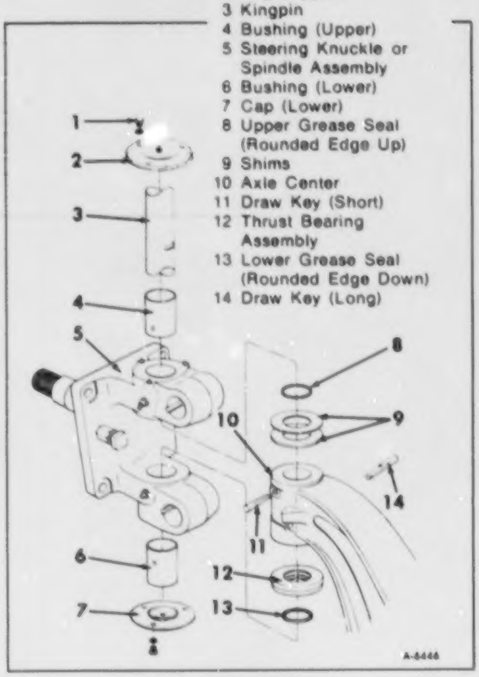
A typical highway truck axle and knuckle assembly is shown in Figure 6-374. Parts of the steering axle are discussed below.



Courtesy of Mack Truck Limited

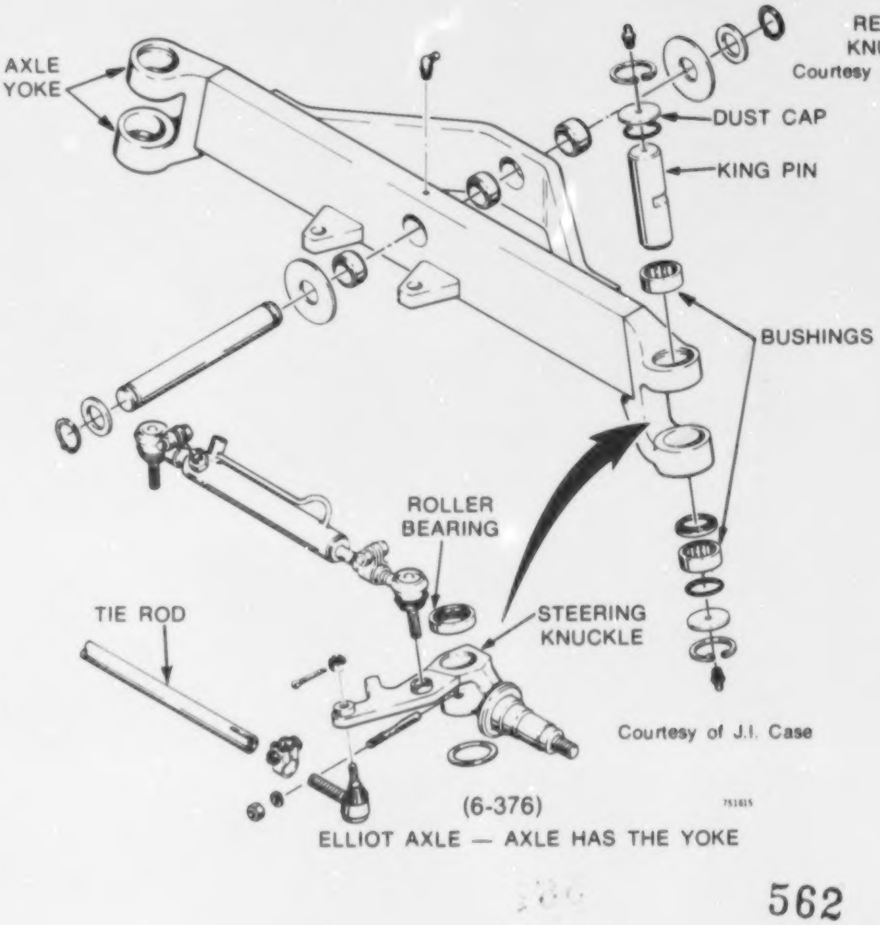
(6-374)

There are two main types of axles: reversed Elliot and Elliot. The difference in the two lies in whether the connecting yoke is on the axle end or on the steering knuckle. On a reversed Elliot axle (Figure 6-375), the yoke is on the steering knuckle whereas on an Elliot axle (Figure 6-376), the yoke is on the axle end. The reversed Elliot is the most common axle.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
A-6446

1 Cap Screw
2 Cap (Upper)
3 Kingpin
4 Bushing (Upper)
5 Steering Knuckle or Spindle Assembly
6 Bushing (Lower)
7 Cap (Lower)
8 Upper Grease Seal (Rounded Edge Up)
9 Shims
10 Axle Center
11 Draw Key (Short)
12 Thrust Bearing Assembly
13 Lower Grease Seal (Rounded Edge Down)
14 Draw Key (Long)

(6-375)
REVERSED ELLIOT AXLE
KNUCKLE HAS THE YOKE
Courtesy of General Motors Corporation


AXLE YOKE
DUST CAP
KING PIN
BUSHINGS
ROLLER BEARING
TIE ROD
STEERING KNUCKLE
751615

Courtesy of J.I. Case

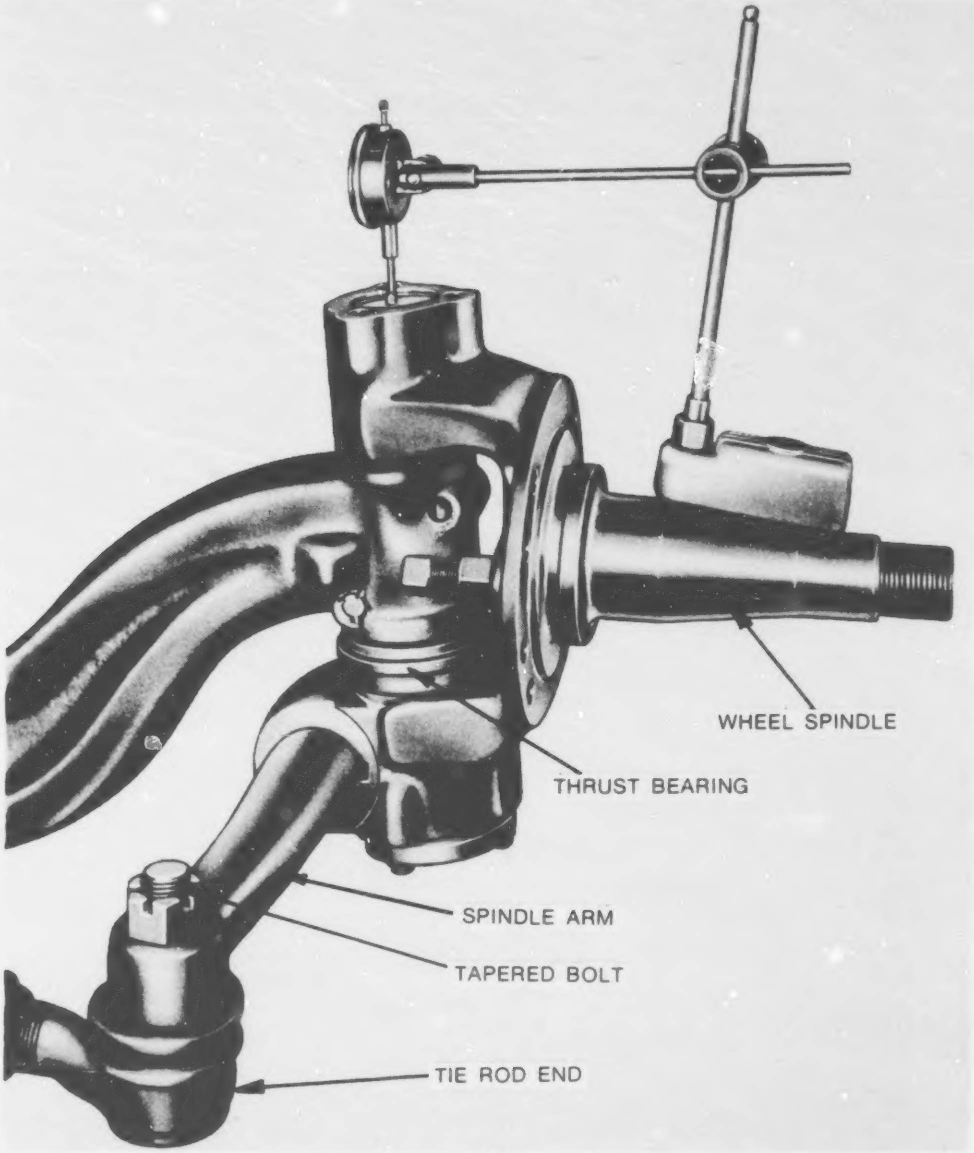
(6-376)
ELLIOT AXLE — AXLE HAS THE YOKE

Steering Knuckle Pins (King Pins)

Non-driving front axles can have straight knuckle pins or tapered knuckle pins. (The two axles in Figure 6-375 and 6-376, both have straight pins.) Straight knuckle pins are held by tapered dowel keys (11) and (14) in Figure 6-375). Tapered knuckle pins are drawn into position and held by a nut at the upper end of the pin. The pins are constructed of a high grade steel and have a case hardened outer surface for strength and resistance to wear.

Steering Knuckle and Bushings

A steering knuckle for a reversed Elliot Axle is shown in Figure 6-377. This knuckle will have bushings in the upper and lower pin bosses and the knuckle will turn around the pin on these bushings. (If the knuckle was for an Elliot axle the bushings would be in the axle pin bosses.) Bushings may be bronze, steel backed bronze or plastic. Whatever their material, all bushings have grooves to allow grease to flow uniformly to the high-pressure areas. Grease fittings are installed in both upper and lower pin bosses. Note that instead of bushings, some machines will use needle bearings as a bearing surface.



(6-377)

Courtesy of Rockwell International Automotive Operations

Besides bushings or needle bearings at knuckle-axle connections, there is also either a ball, a roller or a flat washer thrust bearing which supports the weight of the vehicle and makes steering easier. In the knuckle in Figure 6-377, the thrust bearing is located between the lower pin boss and the axle. In the Elliot axle in Figure 6-376, the thrust bearing is between the upper pin boss and the knuckle.

In addition to a connecting link with the axle, the knuckle has both a flange to which the brake foundation assembly is attached and a wheel spindle. Wheel hubs are mounted on the spindles on opposed tapered roller bearings.

STEERING LINKAGE

Steering Spindle Arms

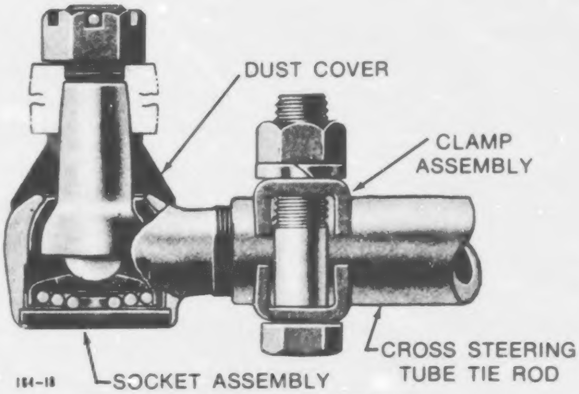
Spindle arms (Figure 6-377) connect the knuckle with the tie rod. The arms may either be bolted or taper fit to the knuckle. The tie rod ends have a tapered bolt which fits into a corresponding tapered hole in the spindle arm. The bolt is secured with a nut.

Tie Rods

The two spindle arms (and thus the two steering knuckle assemblies) are connected to each other by a tie rod (Figure 6-378). The tie rod is threaded at each end and held securely in position by clamp bolts. Right and left hand or "differential" threads are provided on the tie rod to correct wheel alignment. The rod is generally tubular and can be either straight or have a dropped center. In small vehicles multiple tie rods may be used. These will require extra tie rod ends, and an idler arm arrangement to support them.

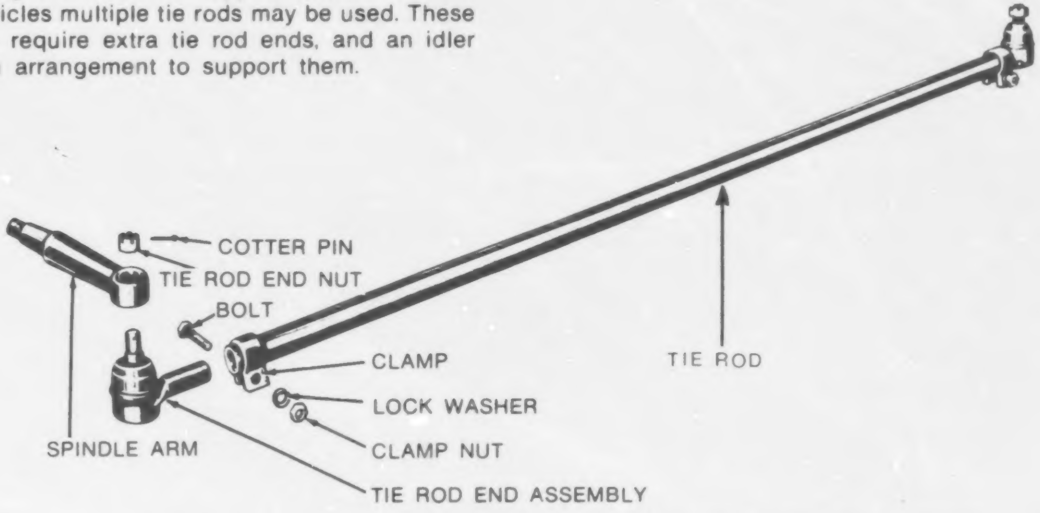
Tie Rod Ends

Tie rod ends (Figure 6-379) are swivel parts that connect the tie rod to the steering arms. They're ball-socket assemblies that are spring loaded and crimped together. Tie rod ends are threaded into the tie rod, and are attached to the steering arm by a tapered stud and nut. A dust cover is placed over the ball stud to keep out water and dirt. A grease fitting is located at the bottom to lubricate the socket assembly. Tie rod ends are usually replaced, although some of the larger ones can be rekitted.



(6-379) TYPICAL BALL SOCKET TIE ROD END

Courtesy of Mack Truck Limited



(6-378)

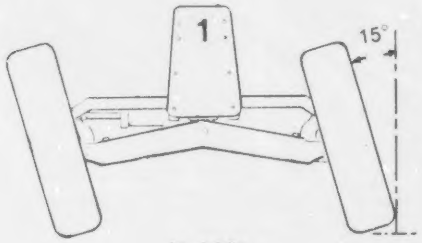
Courtesy of Rockwell International Automotive Operations

Drag Links

A drag link, as was seen earlier, connects the Pitman arm of the steering box to the spindle steering arm. Most drag links have fixed ball-socket assemblies on the ends, and are replaced as a unit. However, some large drag links have replaceable ends that can be rekitted.

Grader Front Suspension

A note should be made here on grader steering since it differs from other wheel vehicles steering: grader front wheels not only turn but also tilt.



(6-380)

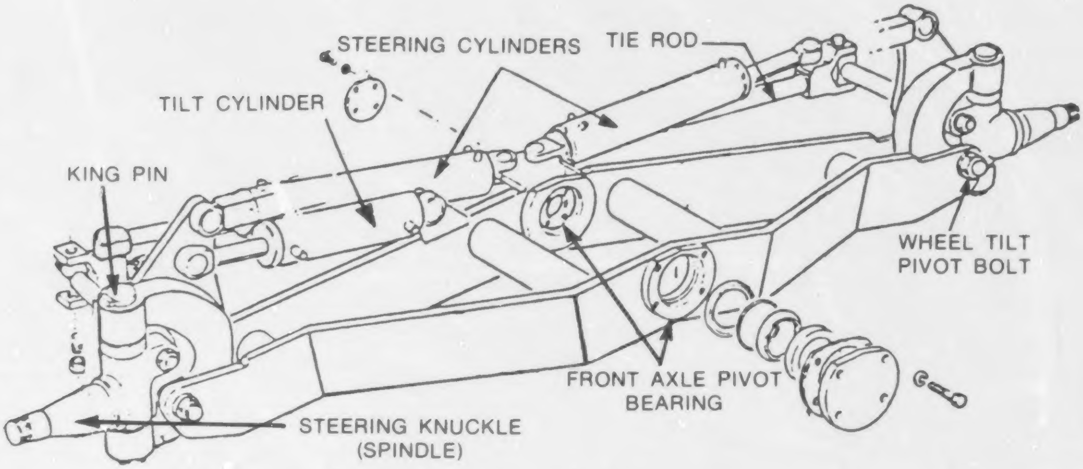
Courtesy of Road Machinery Limited

Tilting the wheels is necessary to offset the side thrust of the grader's moldboard. By tilting the wheels against the direction of thrust, the wheels can dig in and thus reduce the tendency of the light front end to be pushed sideways. Another advantage of the tilting wheels is a shorter turning radius that allows the grader to make sharper turns. Maximum tilt on graders is factory set, usually at 15°.

To get grader wheels to tilt requires some additional parts not seen on trucks. The main additions are:

- — steering knuckle yoke assembly and pivot bolt
- — rod to connect both assemblies together
- — hydraulic tilt cylinder

A typical grader steering axle assembly is shown in Figure 6-381. The steering is power controlled by two hydraulic cylinders. A third hydraulic cylinder tilts the wheels. One end of the tilt cylinder is attached to the axle assembly, and the other end to one steering knuckle yoke assembly. Since both steering knuckle assemblies are connected by a solid rod, movement of the cylinder tilts both wheels together.



(6-381)

Courtesy of Champion Road Machinery Limited

POWER STEERING

In the past most cars used manual steering. Many highway trucks and industrial machines also had manual steering. In modern times the trend has been towards power-assist or full-power steering. The reason for this change is mainly the ease of operation that power gives to steering. On vehicles that normally use manual steering, such as cars and some trucks, power steering provides easier maneuverability, especially in and out of tight spaces. On large off-highway vehicles, power steering is a necessity. The weight of these heavy machines, their large tire-ground contact area, and the soft uneven ground they work in, all would make them very difficult to steer manually. Note that the ease of operation that power gives to steering could also be gained by using higher gear ratios. The problem with the high ratios is that what would be gained in ease would be lost in speed. The steering would be too slow, requiring many turns of the steering wheel to turn the wheels. One other advantage of power steering is that it gives better steering control at higher speeds.

Power steering may be either power-assist, full-power, or hydrostatic. All three types of power steering must:

- — Give the operator a feel of the road.
- — Steer manually if the source of assist fails, or have a back up emergency system in case of power failure.
- — Reduce the tendency to make unwanted turns or to turn too quickly. The wheel should turn only as fast as the steering wheel is turned, and only as far.

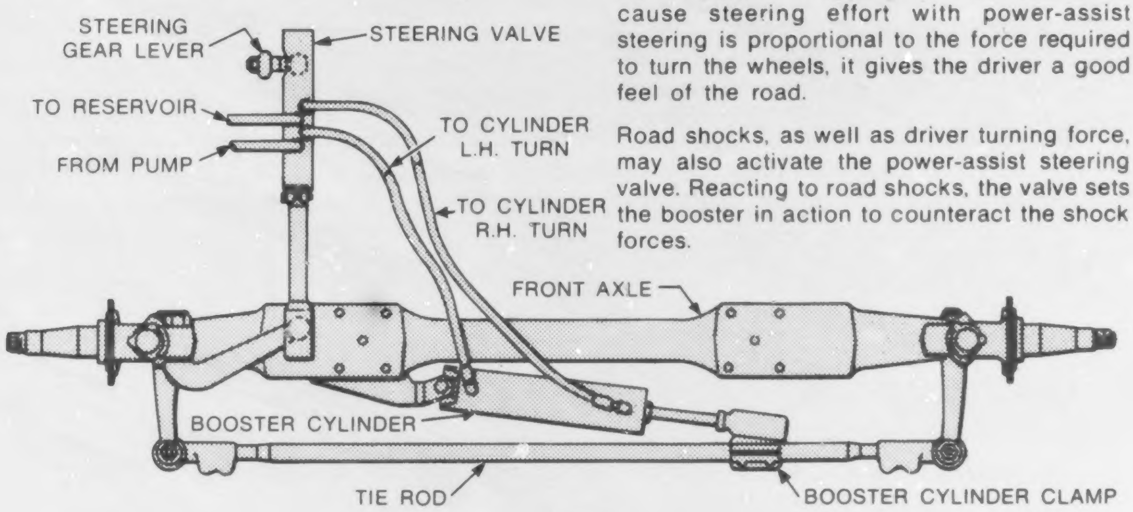
Basic Parts Of A Power Steering System

1. A pump capable of delivering a volume of high pressure oil.
2. A reservoir to store the required volume of oil.
3. Hoses to carry the pressurized oil.
4. Hydraulic cylinder(s) to convert hydraulic pressure to mechanical force and movement.
5. A pressure relief valve.
6. A flow control valve.
7. A directional control valve.
8. Fluid, A.T.F. or a similar type of oil.

POWER-ASSIST STEERING

A typical power-assist steering system is shown in Figure 6-382. Power-assist, often referred to as linkage power steering, is basically a manual steering system with a booster cylinder added. A steering valve (spool valve) located in the drag link senses steering force. When driver effort at the steering wheel reaches a certain point, the valve is activated and sends pressurized oil to the booster cylinder to aid in the turn. When the steering force drops below this point, the assist ceases as the valve piston returns to its center position stopping the flow of oil. Because steering effort with power-assist steering is proportional to the force required to turn the wheels, it gives the driver a good feel of the road.

Road shocks, as well as driver turning force, may also activate the power-assist steering valve. Reacting to road shocks, the valve sets the booster in action to counteract the shock forces.



(6-382)

Courtesy of Mack Truck Limited

Booster cylinders contain a piston attached to a rod that protrudes through the end of the cylinder. The cylinder is usually mounted with its fixed end anchored to the front axle and the piston rod clamped to the tie rod. However, some power-assist linkage steering systems have the cylinder and control valve mounted as an assembly within the drag link. Each end of the double-acting booster cylinder has a port so that steering fluid can be directed into it. Fluid sent to one side causes the booster piston to exert a force on the tie rod in a left direction; fluid to the other side causes the piston to exert a force on the tie rod in a right direction. As steering fluid is admitted to one end of the cylinder during a turn, fluid in the opposite end is discharged to the steering valve and from there goes back to the reservoir.

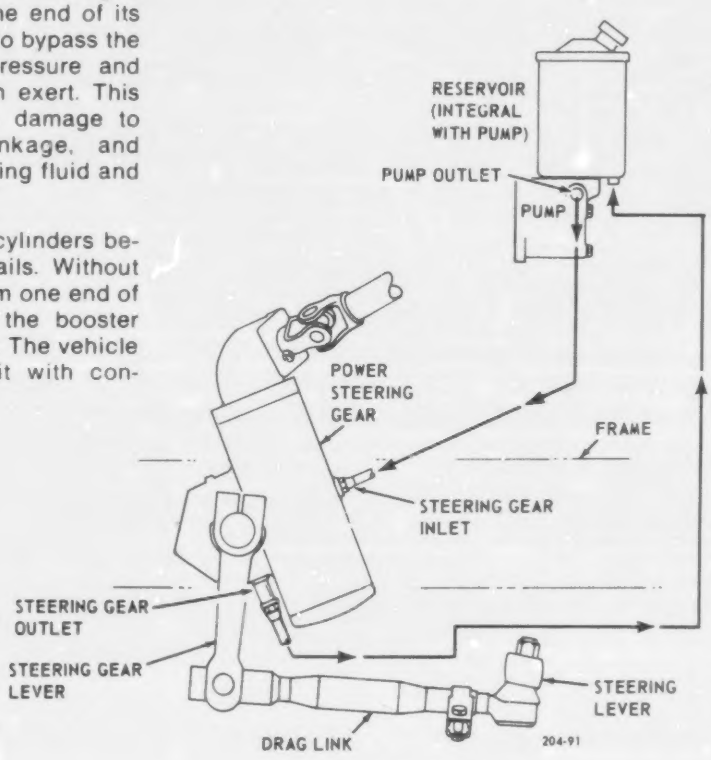
Some booster cylinders relieve pressure automatically as the piston nears either end of its stroke. Relief is accomplished by a taper at each end of the cylinder bore (the end of the bore is larger than the center) so arranged that as the piston approaches the end of its stroke, the taper allows the fluid to bypass the piston, thereby reducing the pressure and limiting the force the piston can exert. This feature automatically eliminates damage to the cylinder and steering linkage, and prevents overheating of the steering fluid and pump.

As a safety precaution, booster cylinders become neutralized if the pump fails. Without pump pressure oil would flow from one end of the cylinder to the other, and the booster would have no effect on steering. The vehicle can be steered manually, albeit with considerably more effort.

The description given here is an example of one type of power-assist steering. Other manufacturers will have different arrangements of the parts. Whatever the design, though, all power linkage systems have the common purpose of providing an assist for turning.

FULL POWER STEERING

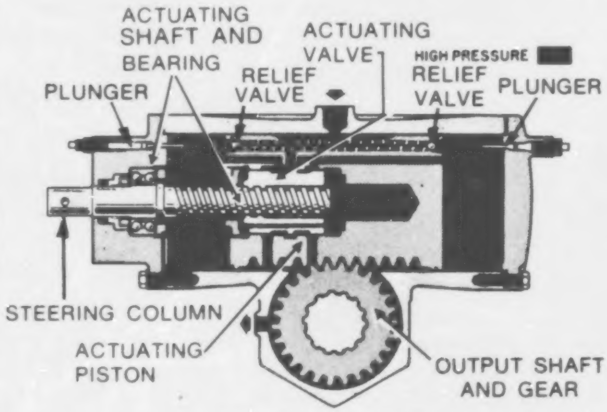
In power-assist steering a control valve and power cylinder are added to manual linkage to reduce the effort needed to turn the vehicle. The power-assist, in effect, is tacked onto a manual steering system. In full-power steering, on the other hand, the power assembly is an integral part of the system because the booster cylinder and control valve are incorporated within the steering gear box. The gear box on full-power steering acts as a hydraulic cylinder. Note in Figure 6-383 that oil is fed directly into the steering box. A full-power system is often called integral power steering.



(6-383)

Courtesy of Mack Truck Limited

The Sheppard steering gear box described here is one of a number of types available; it consists of four basic parts: the actuating shaft, the actuating valve, the actuating piston and the output shaft (Figure 6-384).



NEUTRAL POSITION
(6-384)

Courtesy of Mack Truck Limited

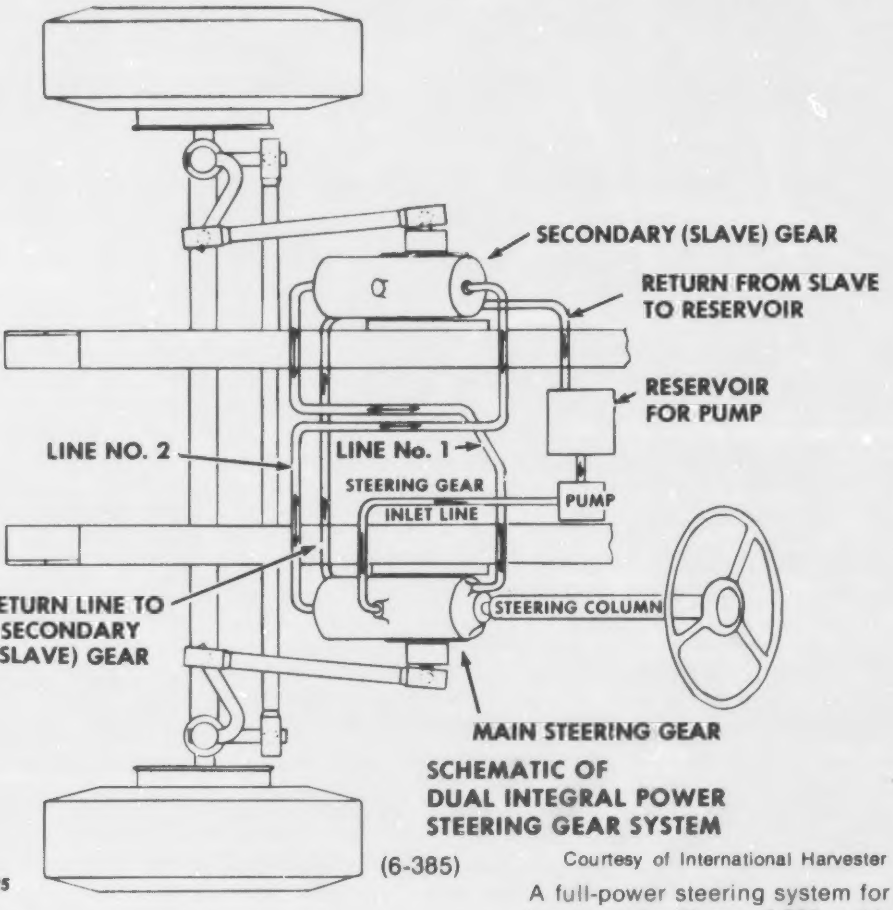
The actuating shaft is connected to the steering column and thus to the steering wheel. The shaft rotates whenever the steering wheel is turned. The actuating shaft has a multiple start thread which is engaged with a similar thread in the actuating valve. The piston has a gear surface called a rack gear cut on one side of it that is meshed with a gear splined to the output shaft. The output shaft has the Pitman arm attached to it. When the actuating shaft is rotated by the steering wheel, resistance created by the vehicle's wheels to the turn causes the actuating valve to move slightly (maximum 1/32") within the piston.

The valve is fitted to a very fine tolerance in a bore in the piston. As the valve moves in response to steering wheel movement, lands and grooves on its outer diameter alternately cover or uncover ports in the piston. As these ports are covered or uncovered, fluid, pressurized by the pump, is directed to the correct end of the piston while at the same time fluid at the opposite end of the piston is returned to the reservoir. As the piston moves back and forth the output shaft is forced to rotate, moving the Pitman arm and thus providing the linear motion to turn the front wheels. A small effort on the steering wheel of this full-power system has resulted in a large effort being applied to the wheels.

When the wheels are straightened after a turn, the activating valve centers, and the hydraulic power no longer acts on the steering. Thus the driver has a good feel of the road when the vehicle is moving straight ahead.

Another important part of the Sheppard integral power steering discussed here is the set of relief valves. These two valves are located in the piston and are activated by plungers at each end of the cylinder housing (Figure 6-384). Either one or both of the plungers is adjustable. Correct setting of the plungers will be dealt with in future training. In operation, the valves serve to relieve hydraulic pressure as the piston approaches the end of the housing. A valve ball is unseated by the portion of the plunger which extends into the cylinder. When the ball is off its seat, pressure cannot be built up. This feature prevents overloading of the hydraulic system and controls the degree of turn. The relief valves also allow the vehicle to be steered manually if the pump fails.

Full-power steering systems are made that have dual steering boxes (Figure 6-385). The box connected to the steering wheel is the control, while the second one is a slave cylinder. The two steering boxes work together to give an increased steering force.

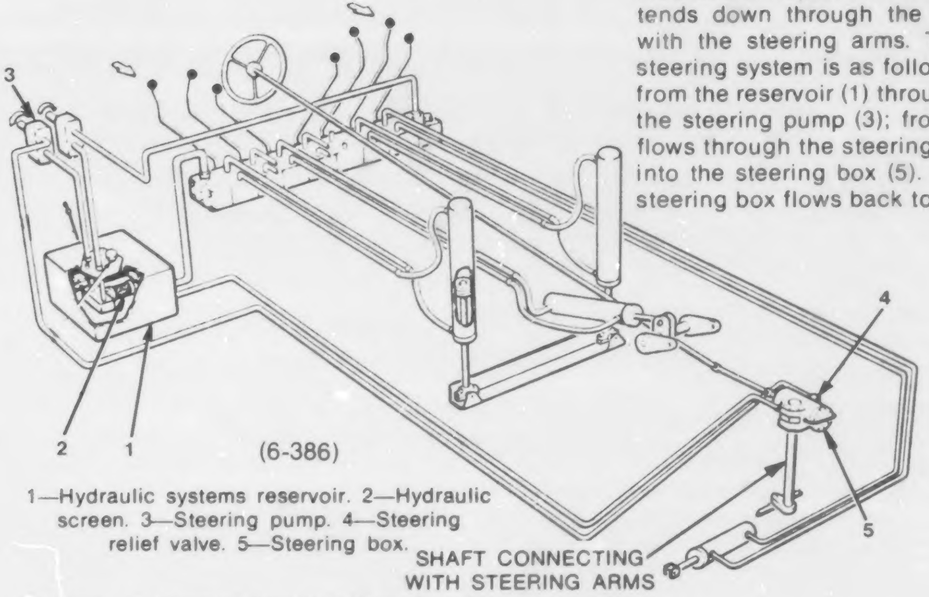

SECONDARY (SLAVE) GEAR
RETURN FROM SLAVE TO RESERVOIR
RESERVOIR FOR PUMP
LINE NO. 2
LINE No. 1
STEERING GEAR INLET LINE
PUMP
RETURN LINE TO SECONDARY (SLAVE) GEAR
STEERING COLUMN
MAIN STEERING GEAR
MT-20625

SCHEMATIC OF DUAL INTEGRAL POWER STEERING GEAR SYSTEM

(6-385)

Courtesy of International Harvester

A full-power steering system for a grader can be seen in Figure 6-386, which shows the machine's full-hydraulic system. The steering parts are numbered. The steering box (5) is mounted on top of the axle bolster. A shaft extends down through the bolster to connect with the steering arms. The oil flow in the steering system is as follows: the oil is drawn from the reservoir (1) through the screen (2) to the steering pump (3); from the pump the oil flows through the steering relief valve (4) and into the steering box (5). Return oil from the steering box flows back to the reservoir. If the


3
4
5
2
1
SHAFT CONNECTING WITH STEERING ARMS

(6-386)

1—Hydraulic systems reservoir. 2—Hydraulic screen. 3—Steering pump. 4—Steering relief valve. 5—Steering box.

Courtesy of Champion Road Machinery Limited

steering box is overloaded, the relief valve opens and the oil bypasses the box and returns to the reservoir. Operation of the steering box is similar to that described for the Sheppard integral system.

Both full-power (integral) steering and power-assist (linkage) steering are generally used on-highway trucks of all sizes and on off-highway vehicles such as logging and gravel trucks. Many types of industrial equipment also use full-power and power-assist steering.

HYDROSTATIC STEERING

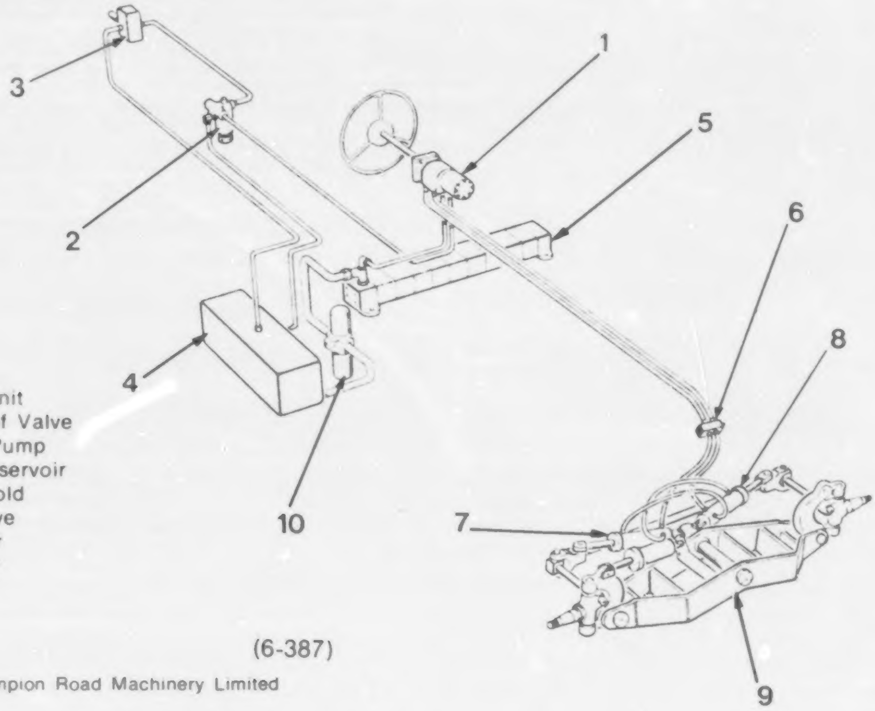
Hydrostatic is a third type of power steering. It is used mainly on slow moving vehicles such as graders, loaders, scrapers, fork lifts and large off-highway haulage trucks. Often hydrostatic steering is also used on articulated machines.

In hydrostatic steering, as opposed to full-power or power-assist steering, the steering wheel is not mechanically connected to the wheels. Turning the steering wheel moves a control valve that directs oil to either a right or left turn hydraulic cylinder. These cylinders supply the force needed to turn the machine. A hydrostatic steering system for a grader is shown in Figure 6-387. It uses an orbital steering control valve made by Char-Lynn.

The oil flow in this Char-Lynn hydrostatic steering system, with the steering wheel in neutral, is as follows: The steering pump (3) draws oil from the hydraulic systems reservoir (4). From the pump the oil flows through the pressure relief valve (2) to the steering unit (1). From the steering unit the oil returns to the reservoir via the double filter assembly (10) and a one-way valve not shown. The one-way valve prevents the oil from escaping out of the reservoir when the filter elements are changed. The steering unit is simply a directional valve that directs oil to the steering cylinders (7 and 8) as the steering wheel is rotated. For example, if the wheel was turned to the left, oil would be directed to the piston rod end of the L.H. cylinder (8) and the anchor end of the R.H. cylinder (7), resulting in the wheels being turned to the left. Return oil flows from the anchor end of the L.H. cylinder and the piston rod end of the R.H. cylinder back to the steering unit.

The steering cushion valve (6) cushions shock loads that the front wheels are subjected to and thus protects the steering cylinders.

The filter assembly (10) consists of two filter elements, one 10 microns and the other 40, which should be changed when the indicator on the filter head is in the red.



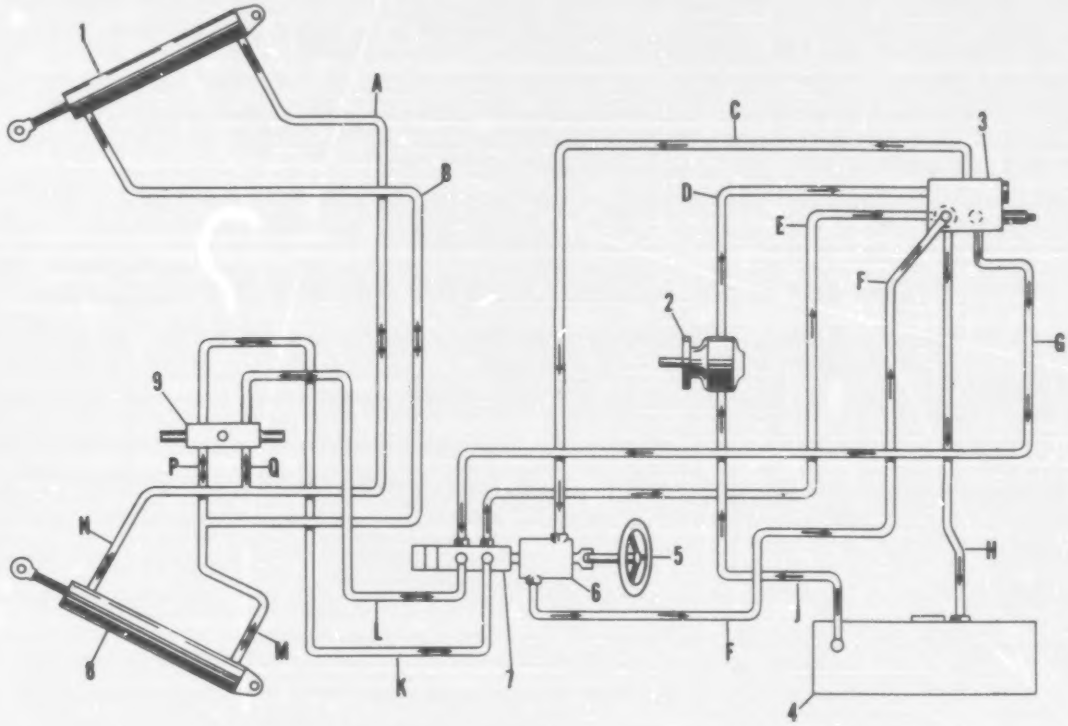
1 Char-Lynn Steering Unit
2 Steering System Relief Valve
3 Steering System Oil Pump
4 Hydraulic Systems Reservoir
5 Main Hydraulic Manifold
6 Steering Cushion Valve
7 R.H. Steering Cylinder
8 L.H. Steering Cylinder
9 Front Axle Assembly
10 Filter Assembly

(6-387)

Courtesy of Champion Road Machinery Limited

A safety precaution is built into this hydrostatic steering system. If the pump should fail, the pressure line closes off and the steering unit, when the steering wheel is rotated, functions as a pump. The steering unit will draw oil from the return line allowing the grader to be brought safely to a stop.

A typical hydrostatic steering system for a large off-highway truck is shown in Figure 6-388. It uses the same hydraulic oil tank (4) for its source of supply as does the main hydraulic system. The steering system consists mainly of the Orbitrol steering valve (7), rotary shut-off valve (6), flow regulator and relief valve (3), double relief valve (9), steering boosters (1 and 8), pump (2), and mechanical linkage on the front axle.



(6-388)

1	R.H. Steering Booster
2	Oil Pump
3	Flow Regulator & Relief Valve
4	Oil Tank
5	Steering Wheel
6	Rotary Shut-off Valve
7	Orbitrol Steering Valve
8	L.H. Steering Booster
9	Double Relief Valve

Courtesy of Terex, General Motors Corporation

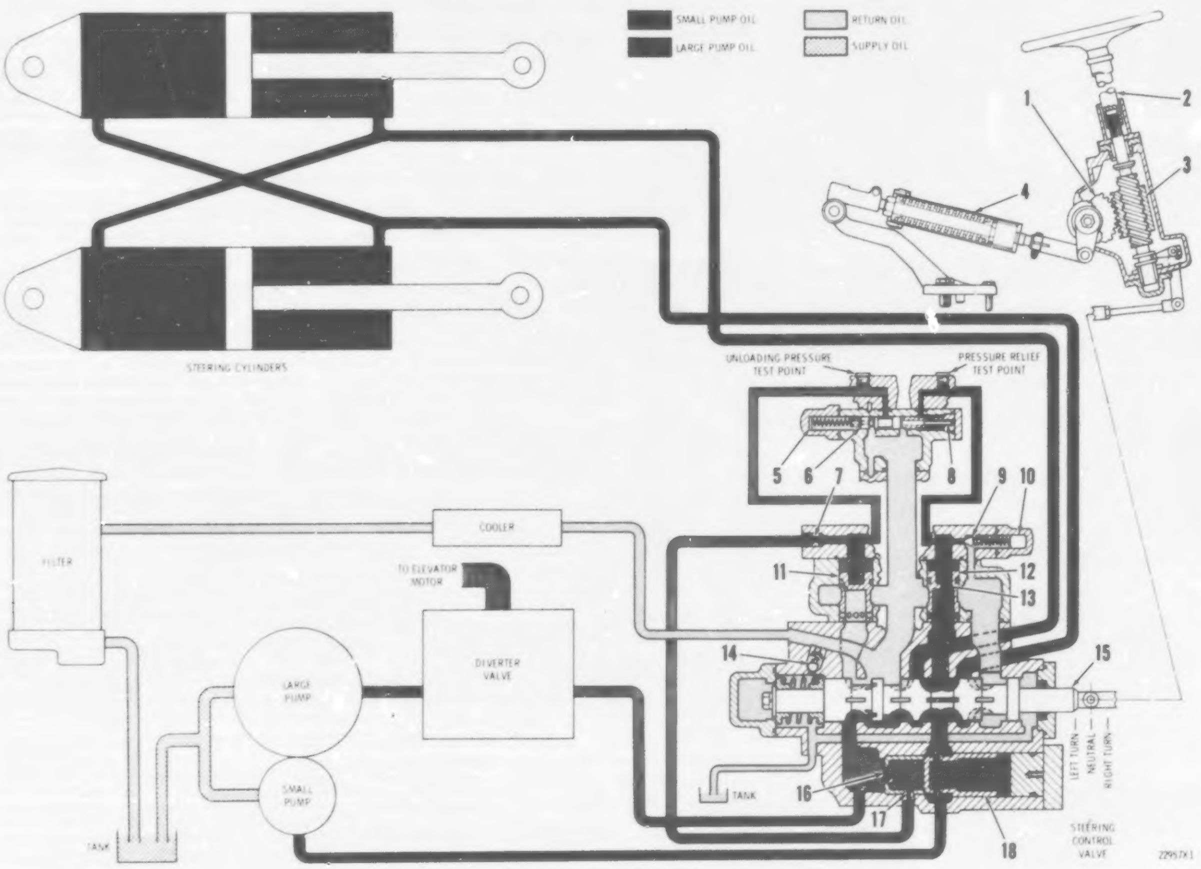
Some articulated loaders and scrapers have hydrostatic steering. The hydraulic steering control used on these machines consists of (1) a mechanical steering assembly coupled by linkage to a hydraulic valve mechanism, and (2) a mechanical link connected between the steering gear assembly and the rear main frame section, referred to as the follow-up linkage (Figure 6-389). This follow-up linkage should not be confused with the steering linkage described earlier that transmitted actual steering force; the only parts that transmits turning force on these machines are the hydraulic cylinders.

Follow-up linkage is connected to the sector shaft at one end, and to the frame via an arm at the other end. This linkage:

1. Aids in returning the control valve to a neutral position after a turn.
2. Moves the control valve to counteract road shock.

When making a turn on one of these articulated machines, movement of the steering wheel, left or right, causes the worm, connected to the steering shaft, to turn inside the restraining nut gear. The resistance created causes an endwise movement of the steering shaft and hence a movement of the hydraulic control valve. The valve directs oil under pressure to the head end and rod end of opposite cylinders, causing the machine to articulate and steer in one direction. The moment the operator releases the effort on the steering wheel, the follow-up linkage, by way of the sector gear, nut gear and steering shaft, returns the control valve to neutral, holding the machine at the desired angle of turn.

STEERING HYDRAULIC SYSTEM


SMALL PUMP OIL
LARGE PUMP OIL
RETURN OIL
SUPPLY OIL
STEERING CYLINDERS
1
2
3
4
UNLOADING PRESSURE TEST POINT
PRESSURE RELIEF TEST POINT
5
6
7
8
9
10
11
12
13
14
15
16
17
18
COOLER
FILTER
TO ELEVATOR MOTOR
DIVERTER VALVE
LARGE PUMP
SMALL PUMP
TANK
TANK
LEFT TURN
NEUTRAL
RIGHT TURN
STEERING CONTROL VALVE
2Z957X1

STEERING SYSTEM SCHEMATIC
(STEERING CIRCUIT IN NEUTRAL AND ACCUMULATOR CHARGED)

1—Sector gear. 2—Steering shaft. 3—Nut gear. 4—Follow-up link. 5—Shims (unloading). 6—Unloading valve. 7—Orifice. 8—Pilot valve. 9—Pilot relief valve. 10—Shims (pilot relief valve). 11—Dump valve (large pump). 12—Dump valve (small pump). 13—Orifice. 14—Ball check. 15—Spool. 16—Orifice. 17—Orifice. 18—Check valve.

(6-389)

Courtesy of Caterpillar Tractor Co.

EMERGENCY STEERING SYSTEMS FOR HYDROSTATIC STEERING

Hydrostatic steering systems have no direct mechanical linkage between the steering wheel and the road wheels. A few years ago, a law was passed making an alternate or emergency method of steering mandatory in the event of an engine or pump failure.

Three emergency steering methods commonly used on hydrostatic steering are:

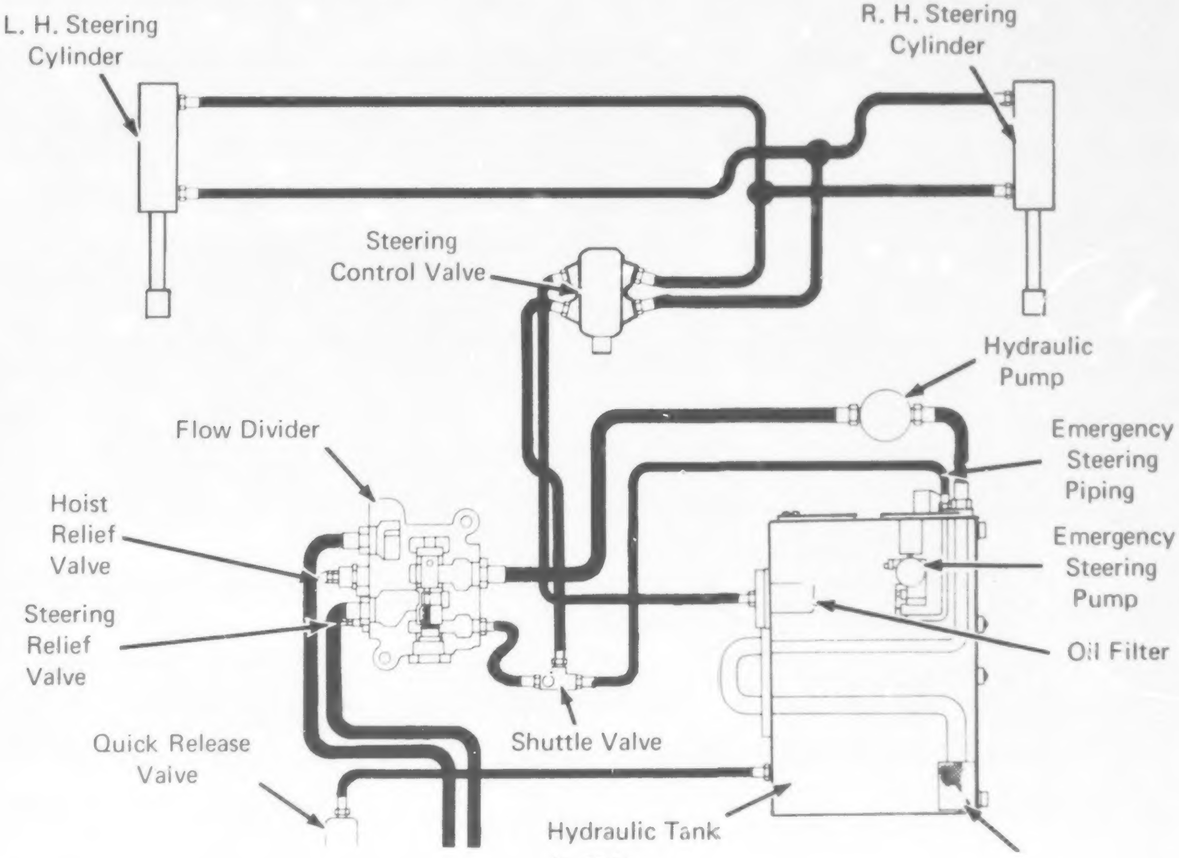
- orbital control
- pump driven by an electric motor
- hydraulic accumulator

Orbital Control

As was mentioned earlier, in the event of an engine or pump failure on an orbital steering system, rotation of the steering wheel converts the internal components of the orbital valve into a rotary pump providing enough control to safely bring the vehicle to a stop.

Pump Driven By An Electric Motor

The electric emergency steering system has an electrically driven hydraulic pump that furnishes sufficient flow and pressure to give the operator enough steering control to stop the vehicle. A switch in the operator's compartment activates the pump. This system is designed for emergencies only and not for continuous service. An emergency steering system can be seen in Figure 6-390 as part of the steering system of a large off-highway dump truck. Notice how the emergency circuit is piped into the main steering system. When the emergency circuit is activated, pressurized oil flows from the emergency steering pump to shift the shuttle valve, cutting off the main hydraulic pump and flow divider from the system. The oil then travels to the steering control valve and steering cylinders and then the vehicle can be safely steered to a stop.


L. H. Steering Cylinder
R. H. Steering Cylinder
Steering Control Valve
Hydraulic Pump
Flow Divider
Emergency Steering Piping
Hoist Relief Valve
Emergency Steering Pump
Steering Relief Valve
Oil Filter
Shuttle Valve
Quick Release Valve
Hydraulic Tank

(6-390)

Courtesy of Wabco Construction and Mining Equipment

Hydraulic Accumulator

An accumulator, as seen in Block 3, Hydraulics, is a cylinder with a precharge of nitrogen gas that is connected into the main hydraulic system to absorb shocks and store pressurized oil.

Oil pressure from the steering hydraulic pump enters the accumulator through a port on the end of the cylinder and compresses a piston against nitrogen gas. The oil pressure thus opposes the gas pressure. As long as oil pressure is maintained in the system, the pressure is maintained against the nitrogen gas. If the oil pressure fails, for some reason, the nitrogen precharge will exert a reverse pressure in the system. The reverse pressure flow, diverted by the accumulator valve to the steering control valve, supplies temporary oil pressure for a short period of steering, usually for two or three full turns. A check valve in the accumulator valve prevents the accumulator pressure from reaching the steering pump.

STEERING GEOMETRY

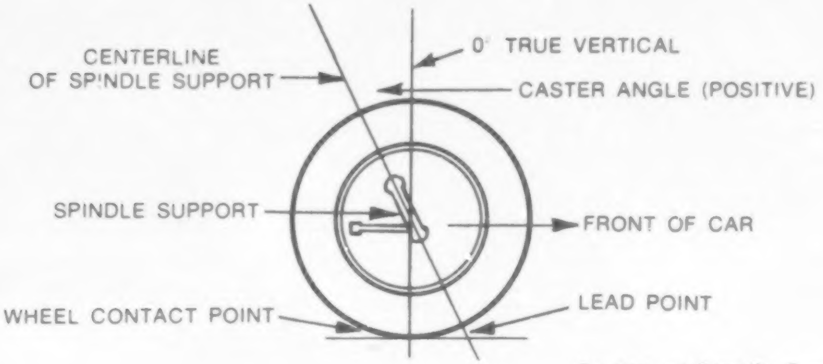
Steering Geometry refers to the angular relationship between the front wheels, steering linkage, and frame. Factors in steering geometry are:

Caster
Camber
Toe-in
Toe-out on turns or turning radius
King pin or steering axis inclination

Each of these factors affects vehicle steering and all but caster influence tire life.

Caster

Caster is the backward or forward tilt of the king pin or spindle support arm. Caster is a directional control angle measured in degrees and is the amount the centerline of the spindle support arm is tilted from true vertical. Tilting the spindle support arm back gives front wheels the tendency to maintain straight ahead position by projecting the centerline of the support arm to a lead point which is ahead of the point of contact of the wheel. Caster **is not** a tire wearing angle.



Courtesy of Snap-On Tools of Canada Limited

(6-391)

Caster is obtained on trucks by placing tapered shims (one on each side) between the axle center spring saddles and the spring (Figure 6-392). When the shims are placed so that the king pins are tilted back, the caster angle is said to be positive. When the king pin tilts forward the caster angle is negative. There are advantages and disadvantages to both angles. Trucks generally have positive caster.

The purpose of caster is to aid directional control of a vehicle. Caster does this by creating a tendency in the front wheels to both maintain a straight-ahead position and return to a staight-ahead position after a turn. Caster also helps offset road crown.

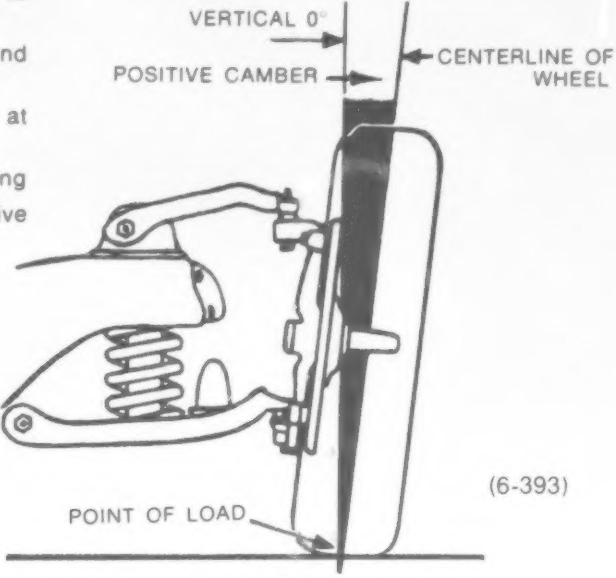
Incorrect caster can cause the following steering problems:

- — Unequal caster causes the vehicle to pull to the side of the last caster
- — Too little caster causes wander and weave
- — Too little caster causes instability at high speeds
- — Too much caster causes hard steering
- — Too much caster causes excessive road shock and shimmy

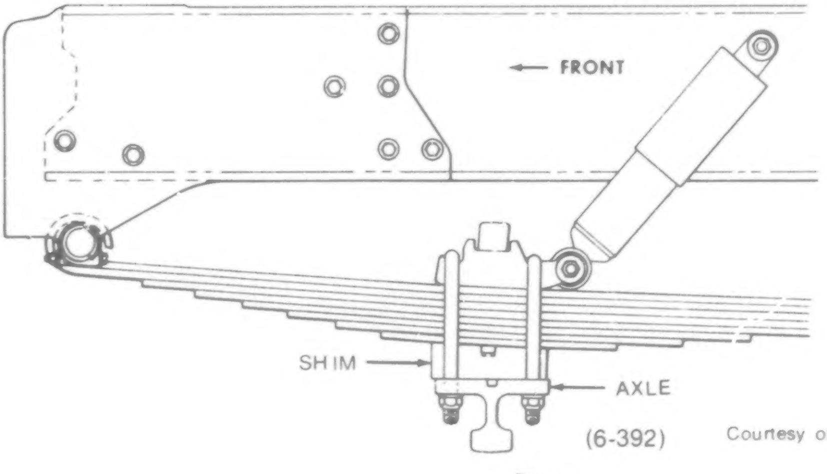
Camber

Camber is the inward or outward tilt of the wheel (in degrees) from the true vertical when the wheels are straight ahead on a level plane. Camber is a tire wearing angle. The camber angle formed when the wheel is tilted outward at the top is said to be positive. When the wheel is tilted inward the camber is negative. Only positive camber is used on vehicles. The purpose of camber is to:

- — bring the road contact of the tire more nearly under the point of the load, thus reducing stress on the axle parts.
- — provide easy steering by having the weight of the vehicle borne by the inner wheel bearing and spindle.
- — prevent tire wear
- — help to eliminate road shock.



(6-393)



A-4053

(6-392)

Courtesy of General Motors Corporation

Since camber is built into a rigid axle, it will not change unless the axle takes on a permanent set from overloading or severe usage, or becomes bent or twisted by hitting an obstruction or colliding with another vehicle.

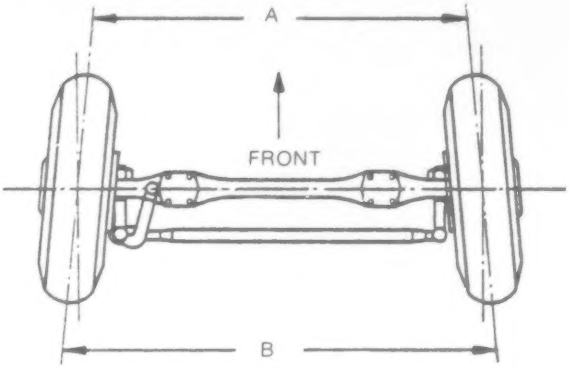
Camber may be checked with a wheel aligning gauge or by measuring the angle formed between the outer edges of the wheel and a square resting on the floor.

The harmful effects of incorrect camber are excessive wear to:

- — ball joints or king pins
- — wheel bearings
- — excessive wear on one side of the tire tread; inside tread wear is caused by negative camber, outside wear by positive camber. Note that although, as was said above, only positive camber is used, over a period of time of wear and tear negative camber will start to appear.

Toe-In

Toe-in is the distance that the front of the front wheels are closer together than the rear of the front wheels (the distance B minus A in Figure 6-394). Conversely, toe-out is the distance the front of the front wheels are farther apart than the rear of the front wheels. Toe-in is considered the most serious tire wearing angle. Incorrect toe-in (or toe-out) appears as a feather-edged scuff across the face of both tires. Because of its harmful effect on tires, it is extremely important that toe-in be checked carefully.



TOE-IN

(6-394)

Courtesy of Kenworth Truck Company

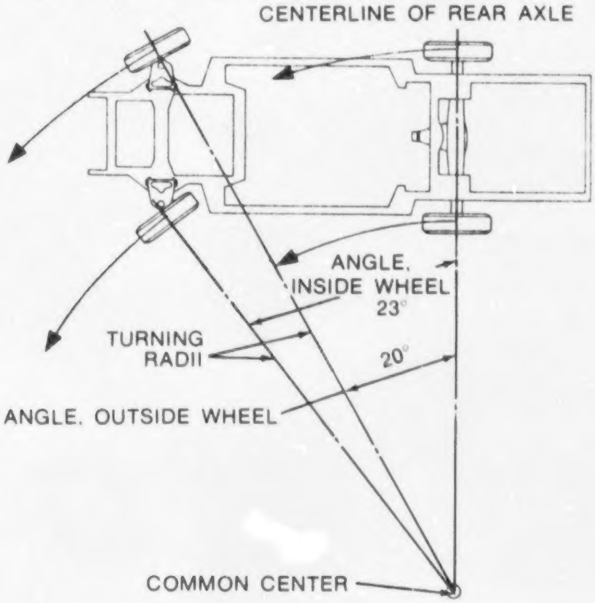
The purpose of toe-in is to offset the small deflections in the front suspension and steering linkage when the vehicle is moving forward. It ensures parallel rolling of the front wheels and tires and minimizes tire wear from scuffing. A toe-in error of 1/8 of an inch is equivalent to dragging the tire crossways 11 feet for each mile the vehicle is driven. To obtain maximum tire mileage, the running toe-in should be zero. The stationary toe-in of a vehicle should be just enough to offset the looseness, and spreading action in the linkage, caused by camber, when the vehicle is being driven forward.

Trucks using bias ply tires generally call for 1/16 inch toe-in, while those using radial ply tires call for a zero toe-in. Toe-in amounts for automobiles are somewhat higher due to their more flexible front suspension.

Turning Radius (Toe-Out On Turns)

When rounding corners, the front and rear wheels must turn about a common center with respect to the radius of the turn (Figure 6-395). The front end design of most motor vehicles is such that the front wheels pivot independently and at different distances from the center of the turn. This makes it necessary to have the wheels turn at different angles. The inside wheel, being ahead of the outside wheel, must turn at a sharper angle than the outside wheel in order to remain perpendicular to the radius and prevent the tires from scrubbing. The sharper turning angle of the inside wheel is called toe-out on turns. Toe-out on turns is accomplished by bending the steering arms slightly inward toward the center of the vehicle.

Note that toe-out on turns does not affect the wheels in straight ahead position. The wheels must return to their original parallel position after the turn is completed.



(6-395) TURNING ABOUT A COMMON CENTER
Courtesy of Ford Motor Company

Toe-out on turns is not adjustable, and any deviation from specifications would indicate bent steering arms or bent, worn, or damaged linkage. Improper toe-out on turns will result in tire wear similar to that caused by improper toe-in adjustment.

King Pin Inclination

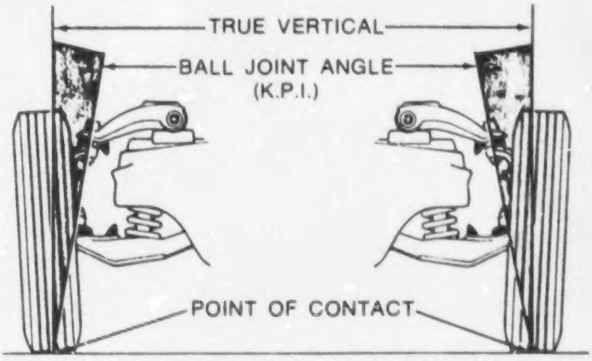
King pin inclination (K.P.I.) is the tilt of the king pin or ball joint steering axis toward the center of the vehicle. (Caster is the tilt of the king pin toward the back of the vehicle.)

The purpose of K.P.I. is to:

- — bring the extended centerline of the pivot closer to the center of tire-road contact and thus reduce the scrub radius (Figure 6-396).
- — give the vehicle straight ahead directional stability.

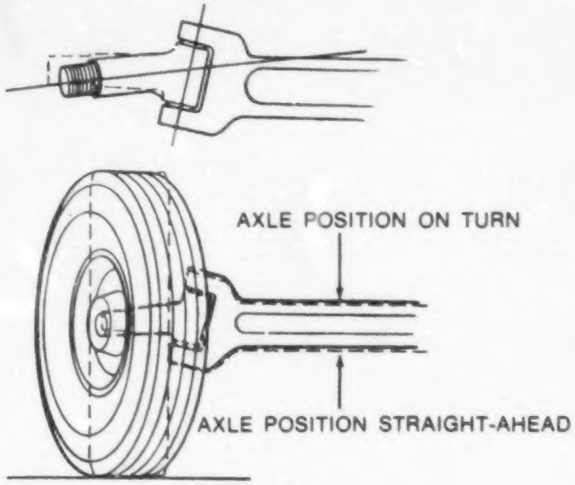
King pin inclination adds to directional stability in the following way:

> When the front wheels are turned to the right or left, the spindle revolves around the pivot. Because of the angle of the pivot, the end of the spindle describes an arc. The ends of the arc are closer to the road surface than the top of the arc (Figure 6-397). Since it is impossible for the end of the spindle to get closer to the road surface because of the wheel and tire, it follows that the front of the vehicle must be slightly raised when the wheels are turned from the straight-ahead position. Because of the effort needed to raise the front end on turns, the wheels will have a resistance to turning and tend to travel straight-ahead. Also, after a turn the wheels will have a tendency to return to a straight-ahead position as the weight of the vehicle at the axle will be moving from a higher to a lower position. A similar principle is used when a door is hung at a slight angle: the door, when unlatched, won't open by itself and will have a tendency to close if left open. Note that the resistance to turns caused by K.P.I. is not enough to cause hard steering.



(6-396) KING PIN OR BALL JOINT INCLINATION
Courtesy of Ford Motor Company

Caster, as discussed earlier, is the tilt of the king pin toward the back of the vehicle. Caster, therefore, has an effect on K.P.I. The effect, though, is not significant, since caster angle is generally small.



(6-397)

Courtesy of Ford Motor Company

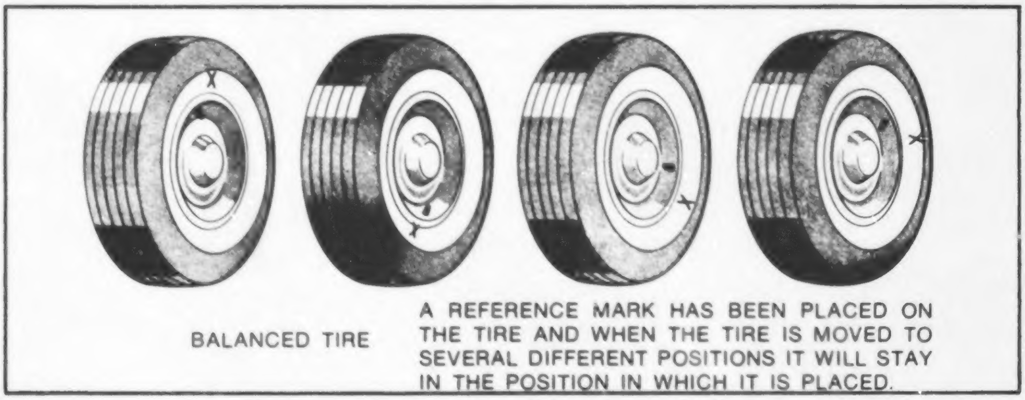
Like camber, king pin inclination is fixed by the design of the axle and will not change unless the axle has been bent from overloading or impact forces. King pin inclination may be checked with a wheel aligning gauge.

WHEEL BALANCE AND UNBALANCE

Proper tire and wheel balance is essential for good steering and handling. Unbalanced wheels and tires can result in shimmy and erratic steering conditions. There are three types of wheel unbalance: static, kinetic, and dynamic.

Static

A static unbalance condition exists in a wheel when (1) the wheel has a heavy spot, and (2) the wheel is not rotating. A wheel is said to be in static balance when it has the weight equally distributed around the circumference (i.e., it has no heavy spots) in such a manner that there is no tendency for the wheel to rotate by itself when it hangs free (Figure 6-398). Conversely, if a wheel has static unbalance, it has a heavy spot(s) that would cause the wheel to rotate so that the heavy spot rests at the bottom.



A REFERENCE MARK HAS BEEN PLACED ON THE TIRE AND WHEN THE TIRE IS MOVED TO SEVERAL DIFFERENT POSITIONS IT WILL STAY IN THE POSITION IN WHICH IT IS PLACED.

(6-398)

Courtesy of Ford Motor Company

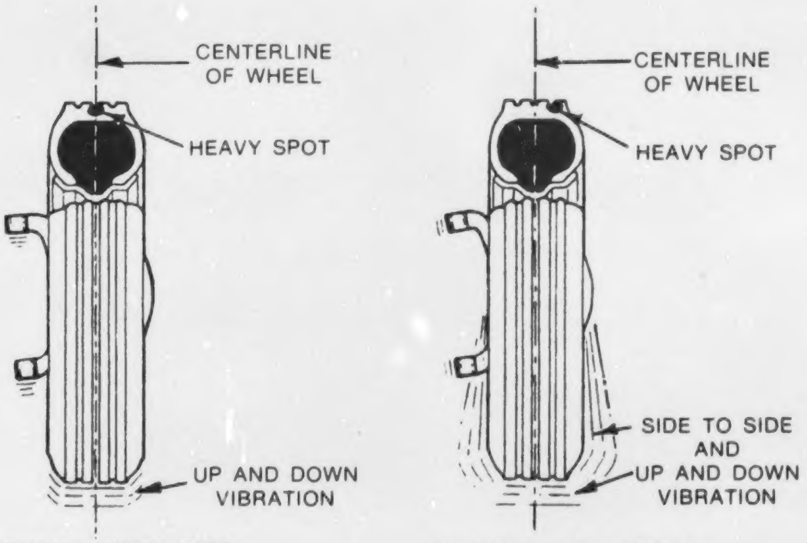
Kinetic and Dynamic

Kinetic and dynamic unbalance conditions occur in a wheel when (1) static unbalance condition exists in the wheel, and (2) the wheel is rotating.

The relationship between kinetic and dynamic unbalance depends on the location of the heavy spot on the wheel. If the heavy spot is located exactly on the centerline of the wheel (Figure 6-399), only kinetic unbalance occurs. If the heavy spot is located toward either side of the centerline of the wheel (Figure 6-399), both dynamic unbalance and kinetic unbalance occurs.

Kinetic unbalance causes up and down vibration. Dynamic unbalance causes side to side vibrations. Since kinetic and dynamic unbalance usually occur together, the resulting vibrations are a combination of up and down and side to side vibrations. A wheel with dynamic or kinetic unbalance can be balanced by placing weights on the wheel rim 180 degrees away from the heavy spot. Centrifugal force acting on the weights will equal the centrifugal force acting on the heavy spot and cancel out the forces trying to move the wheel's rotating axis.

An unbalanced wheel causes tire wear. The tire on a wheel that is run unbalanced for sometime will have a wavy tread surface.



KINETIC UNBALANCE DYNAMIC UNBALANCE

(6-399)

Courtesy of Ford Motor Company

QUESTIONS — WHEEL VEHICLE STEERING

1. Through the actions of the steering gear in a manual steering system, rotary motion of the steering wheel is converted to:
   (a) vertical motion of the linkage
   (b) sideways motion of the linkage
   (c) linear motion of the linkage
   (d) one-way motion of the linkage
2. Synchronized movement of the two wheels is accomplished by connecting them together with a:
   (a) drag link
   (b) steering arm
   (c) sway bar
   (d) tie rod
3. The drag link connects the:
   (a) steering knuckles together
   (b) steering gear to the cross shaft
   (c) Pitman arm to the tie rod
   (d) Pitman arm to the steering control arm
4. What are the three basic types of wheel vehicle steering systems?
5. What are the three common types of manual steering gears used in heavy duty equipment.
6. True or False? Recirculating ball steering gears are more common on heavy duty vehicles than worm and roller steering gears.
7. The worm on a worm and roller steering gear is __________ shaped, whereas the worm on a recirculating ball gear is __________.
8. A cam and lever steering gear uses:
   (a) a sector gear
   (b) a roller gear
   (c) a lever and stud arrangement instead of a gear
   (d) any of the three can be used
9. Why is a swinging shackle needed on a leaf spring?
10. Unlike those on automobiles, most heavy duty spring shackle pins and bushings have __________.
11. A leaf spring is properly located on the axle mounting pad by means of the:
    (a) spring hanger
    (b) center bolt
    (c) spring shackle
    (d) rebound clips
12. The purpose of shock absorbers is to:
    (a) help the spring support the load
    (b) act as an overload device
    (c) control spring oscillations
13. True or False? A shock absorber works on the principle of a drag being created when fluid moves through restricting orifices.
14. On a vehicle with a reverse Elliot front axle, the thrust bearing is positioned between the steering knuckle and:
    (a) the top of the axle eye
    (b) the bottom of the axle eye
    (c) either (a) or (b), depending on the machine
15. What is the brake foundation assembly attached to?
16. Are there any grease fittings at the axle knuckle connection?
17. Compared to other wheel vehicle steering systems, what additional function must grader steering perform?
18. A ____________________ is used to tilt the front wheels on a current grader.
19. Besides giving ease of operation, power steering is necessary on large off-highway equipment because of difficult steering caused by:
    (a) the weight of these machines
    (b) their large tire-ground contact area
    (c) the soft uneven ground they work in
    (d) all of the above are correct
20. What are the three basic types of power steering?
21. What are the two locations where the booster on power-assist (linkage) steering is located?

22. In a linkage power steering system, the spool valve is located in the:
    - (a) steering gear
    - (b) steering box
    - (c) power piston
    - (d) steering linkage (drag link)

23. Another name for full-power steering is ________________.

24. On integral power steering, the control valve is located in the:
    - (a) tie rod
    - (b) steering box
    - (c) drag link
    - (d) steering shaft

25. How does a hydrostatic steering system differ from linkage or full-power steering?

26. What happens in the steering unit (i.e., the orbital control valve) of a hydrostatic steering system when the steering wheel is turned?

27. True or False? The follow-up linkage used in steering on some articulated machines transmits all the steering force between the two frame halves.

28. What is the function of the emergency steering system on hydrostatic steering? What are the three common types of emergency systems?

29. Briefly explain the term steering geometry.

30. Caster may be defined as:
    - (a) the inward or outward tilt of the wheel
    - (b) sideways inclination of the king pin
    - (c) forward or backward tilt of the king pin
    - (d) none of the above

31. When a caster shim is placed so that the thick end of the shim faces the rear of the vehicle, the vehicle has:
    - (a) positive caster
    - (b) negative caster
    - (c) increased K.P.I.

32. True or False? Positive caster helps keep the wheels moving straight-ahead.

33. Positive camber is created by:
    - (a) tilting the axle or spindle assembly backward
    - (b) an angle in the axle that tilts the top of the wheels outward.
    - (c) using a larger inner wheel bearing.

34. True or False? Camber is a tire wearing angle.

35. Excessive wear to the outside of a tire tread indicates too much:
    - (a) positive caster
    - (b) positive camber
    - (c) negative caster
    - (d) negative camber

36. An incorrect camber setting on a rigid front axle:
    - (a) cannot be adjusted without bending the axle
    - (b) can be adjusted by shimming the axle
    - (c) can be corrected by changing the size of the inner wheel bearing
    - (d) can be corrected by installing a spindle of a different angle

37. Toe-in on a solid axle truck suspension can be adjusted by:
    - (a) shimming the spring pad and spring pack
    - (b) bending the axle
    - (c) adjusting the length of the drag link
    - (d) adjusting the length of the tie rod

38. True or False? Toe-out on turns is achieved by having the steering arms bent slightly inward toward the center of the vehicle.

39. The purpose of king pin inclination is to:
    - (a) offset negative caster
    - (b) provide a means of adjusting caster
    - (c) make turning easier
    - (d) bring the steering pivot axis nearer the center of tire-road area contact

40. A wheel with a heavy spot is ______________.

41. A static wheel balance machine checks the wheel for ____________. To check wheel balance dynamically, the wheel is spun and inspected to see if it ________________.

42. If a heavy spot was exactly on the centerline of a rotating wheel, what kind of unbalance would exist and what kind of motion would occur in the wheel?

43. An unbalanced wheel can be corrected by placing the right amount of weight on the rim:

    (a) 80° from the heavy spot
    (b) 100° from the heavy spot
    (c) 180° from the heavy spot
    (d) 90° from the heavy spot.

MAINTENANCE AND SERVICE REPAIR OF WHEEL MACHINE STEERING AND FRONT SUSPENSIONS

DAILY, ROUTINE MAINTENANCE

Steering and suspension are directly related to safe vehicle operation and therefore should be checked regularly. Daily, routine checks for the steering and front suspension will include checking for:

- — Correct tire pressure. Also check that tires are in good operating condition.
- — Loose wheel lugs, broken or missing wheel nuts and studs.
- — Loose, damaged or bent steering linkage.
- — Oil leaks that may have developed around power steering parts.
- — Loose U-bolts (see (Figure 6-272) and cracked or broken spring leaves.

SCHEDULED MAINTENANCE

Scheduled maintenance for steering and suspension involves lubricating all steering and suspension parts of the intervals recommended by the manufacturer. When a vehicle is lubricated, a thorough visual inspection should also be carried out. This inspection should take in the daily, routine checks listed above as well as more thorough checks that would include checking for:

- — Bent tie rods.
- — Loose tie rod ends.
- — Looseness of the drag link at the ball stud sockets and tube clamp bolts. Also check that the clamp bolts are in the right position and are not interfered with.
- — Loose steering gear mounting bolts, cover retaining bolts, and steering gear lever nut or pinch bolt. Also check the steering gear frame mounts for cracks.
- — Excessively worn or loose steering universal joints.
- — Excessively loose king pins or wheel bearings.
- — Loose or missing bolts or rivets on spring hangers. Also check for frame cracks at hanger mounts.
- — Excessive play of articulated machine's pivot points.

Also, as part of scheduled maintenance on a steering system, the steering gear should be checked for wear and adjusted as required. Adjustment is necessary when back lash at the steering gear is perceptible within three quarters of a turn to either side of center. However, check for loose linkage or wheel bearings before proceeding with a steering gear adjustment.

The only adjustment generally done to manual steering boxes on the vehicle is to adjust sector backlash. The term sector backlash refers to worm and roller, and cam and lever steering gears (as well as to recirculating ball steering gears even though they technically don't have a sector gear). To make this adjustment it is best to raise either the vehicle so that the wheels are clear of the floor or disconnect the drag link. The adjustment is made with the wheels in the straight-ahead position and the steering box on the high spot. Adjust as outlined in the service manual. After adjusting, if you notice a bind when the wheels are turned from full left to full right, recheck the adjustment. If the adjustment is correct, it could indicate a problem within the steering box, in which case the box would have to be removed and repaired.

Steering Lubricants

Steering lubricants may be divided into three areas: steering linkage, manual steering gears, and power steering units. Each area uses a different lubricant: check the service manual for the recommended type.

1. Steering linkage — For king pins, drag link, tie rod ends, pivot points, shackle pins, etc., use a good grade of chassis grease such as a lithium or Moly base.
2. Manual steering gears — many manual steering gears use S.A.E. 80 GL5 gear oil, although a different lubricant is recommended by some manufacturers, e.g., G.M.
3. Power steering systems — lubricants for power steering systems vary a great deal. Some of the common ones are:

   S.A.E. 10 Engine oil with API, SD or SE Specifications

   A.T.F. (Automatic Transmission Fluid)

   C2 Torque fluid

   Type F Automatic Transmission Fluid

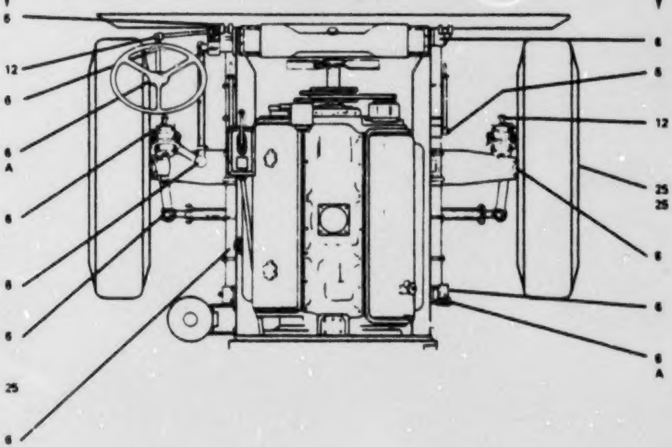
Figure 6-400 shows a typical lubrication chart for an on-highway truck showing only the steering and front suspension. Lubricants and intervals are given in keys.

Note On Grease Gun Use

Pressure guns should be held on fittings until new grease appears. The appearance of new grease will assure that all the old contaminated grease has been forced out. Experience has shown that the best distribution of new lubricant and the best purging of old lubricant is obtained when approximately 4,000 p.s.i. pressure is applied at the grease gun nozzle.

LUBRICATION CHART

K-100 SERIES



	LUBRICANT	INTERVAL
CAB TILT PIVOTS	CL	6
STEERING U-JOINTS		
(One fitting each end)	CL	12
STEERING SLIP JOINT	CL	6
STEERING GEAR BOX		
Check oil level	GO	6
Drain and refill	GO	A
FRONT BRAKE CAMSHAFT		
(Lubricate sparingly) (See brake notes, over)	BG	6
DRAG LINK		
(One fitting each end)	CL	6
TIE-ROD ENDS		
(One fitting each side)	CL	6
BRAKE TREADLE		
(NOT SHOWN) Hinge and roller	EO	25
OWER STEERING RESERVOIR		
Check fluid level		6
Change fluid and filter		A
Vickers & Garrison	HTF	
Ross (Integral)	ATF	
Sheppard (Integral)	EO	

INTERVAL	LUBRICANT	
		SPRING PINS
6	CL	(One fitting each side)
6	EO	CAB LIFT CYLINDER ANCHOR PINS
		FRONT SLACK ADJUSTERS
12	BG	(Lubricate sparingly) (See brake notes, over)
		FRONT WHEEL BEARINGS
25	GO	Oil lubricated
25	CL	Grease lubricated
		KING PIN
6	CL	(Two fittings each side)
		SPRING SHACKLE PINS
6	CL	(Two fittings each side)
		CAB TILTING PUMP
6	HY	Check fluid level
A	HY	Drain and refill

INTERVAL KEY	
6	6,000 Miles (10 000 km)
12	12,000 Miles (20 000 km)
25	25,000 Miles (40 000 km)
A	Annually
AR	As Required

LUBRICANT KEY

BB – Ball Bearing Grease, EP
BG – Brake Grease (See notes, over)
CL – Chassis Lube
EO – Engine Oil
GO – Gear Oil
HY – Hydraulic Cylinder Oil
ATF – Automatic Transmission Fluid
HTF – Hydraulic Transmission Fluid, Type C 2
SL – Silicone Lubricant
LL – Lock Lubricant
PG – Polyethylene Grease Stick

NOTE: Refer to the Lubrication Specification Chart for recommended lubricants and service intervals. The service intervals noted above are for normal operating conditions only.

(6-400)

Courtesy of Kenworth Truck Company

Front Wheel Bearing Packing and Adjusting

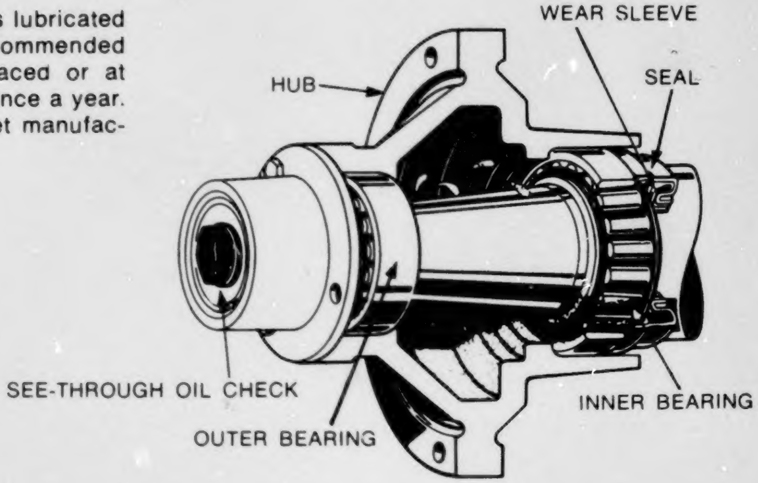
Periodic inspection of wheel bearings, as well as regular lubricant changes, are necessary for maximum wheel bearing life. The frequency of lubricant changes depends upon individual vehicle operating conditions, speeds and loads. Under normal conditions, the following lubrication intervals for wheel bearings are recommended for on-highway trucks:

> **Grease Lubricated** — For bearings that are lubricated with grease, changes are recommended whenever the seals are replaced or brakes are relined or at 25,000 to 30,000 mile intervals. For vehicles operating less than 30,000 miles annually, the lubricant should be changed twice a year. Wheel bearing grease should meet manufacturer's specifications.
>
> **Oil Lubricated** — For bearings lubricated with oil, changes are recommended whenever the seals are replaced or at brake reline time, or at least once a year. Wheel bearing oil should meet manufacturer's specifications.

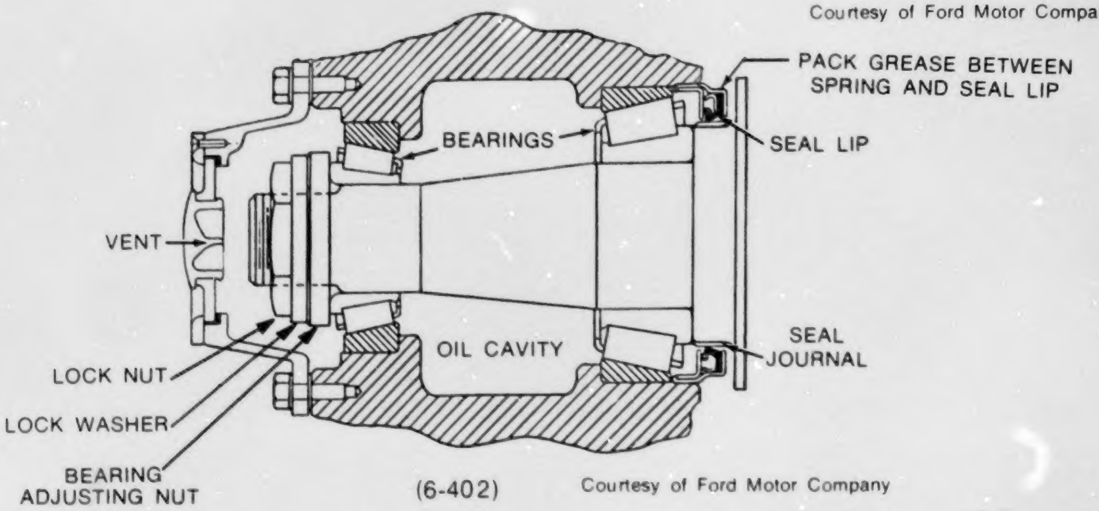
REMOVING FRONT WHEEL BEARINGS

Before wheel bearings can be inspected or packed, they must be removed. Two views of wheel bearings are shown in Figures 6-401 and 6-402. Bearing removal involves jacking the vehicle up so that the wheel clears the floor, and then removing the wheel and hub as an assembly. After the hub cap (dust cap) and bearing adjusting nut are removed, the wheel and hub assembly are slid from the spindle with care taken not to drag the hub or inner bearing cone over the spindle threads.

The outer bearing race will fall out as the hub and wheel are removed. The inner race can be easily removed by driving it out with a drift from the outside toward the inside. The grease seal will be pushed out at the same time, usually without damaging it.



(6-401)
Courtesy of Ford Motor Company



(6-402) Courtesy of Ford Motor Company

Cleaning and Inspecting

Clean all old grease or oil from the bearings and from hub cavities with solvent, kerosene or diesel fuel oil and a stiff brush. After cleaning, the bearings should be dried with compressed air. Direct the air across the bearings: never spin bearings while blowing them dry. Clean the spindle, as well. Always dry parts before lubricating them. Grease or oil will not adhere to a surface which is wet with solvent and besides, the solvent may dilute the lubricant.

Inspect bearings for excessive wear, chipped edges and other damage. Slowly roll the rollers around the cone to detect any flat or rough spots. Replace damaged bearings. If cups are pitted or cracked, they must be replaced. (See the section on bearings at the beginning of this block.)

Also inspect the hub oil seal(s). New hub oil seals should be installed when there is the slightest indication of leakage, wear, or damage. An imperfect seal may permit bearing lubricant to reach brake linings, resulting in faulty brake operation and a premature replacement of linings. The recommended practice is to replace the seal.

Packing and Lubricating

Grease Packed Bearings

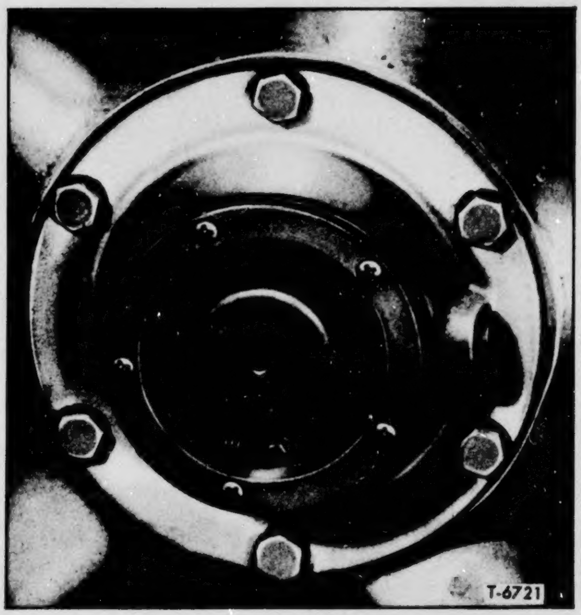
See the service manual for the correct type of grease to use. Pack the bearings with a pressure packer if possible. If a packer is not available, pack the bearings by hand, forcing the grease into the cavities between the rollers and cage from the large end of the cone. As well cover the ends of the rollers freely with grease. Fill the wheel hub with grease to the inside diameter of the outer races and also fill the hub grease cup (see the shaded areas in Figure 6-402). Also, apply a film of grease on the bearing spindle to prevent rust from forming behind the inner bearing cone.

Note: Always complete the job of assembling the wheel on the spindle after packing the hub and bearing to avoid accumulating dust and grit on greased surfaces.

Oil-Lubricated Bearings

Lightly coat the bearings with oil. Also wipe a film of oil on the bearing spindle to prevent rust from forming behind the inner bearing cone. Install the inner bearing and seal, and carefully install the hub over the spindle. Install the outer bearing and adjust it (see below). Care should be taken to correctly install the hub cap gasket because oil leakage could occur here. Install the cap (the cap and plug should be clean), torquing the cap bolts evenly.

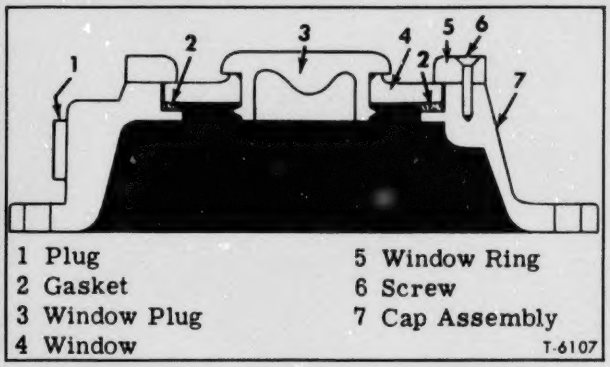
Fill the hub with oil to the level indicated on the cap (Figure 6-403). Wait a sufficient time for the lubricant to find its level. Rotate the wheel and recheck the lubrication level.



OIL LEVEL (BEARINGS)

Courtesy of General Motors Corporation

(6-403)



OIL LUBRICATED BEARINGS
(HUB CAP)

INSTALLING WHEEL SEALS

Coat the lip of the seal with grease. On double lip seals fill the cavity between the lips with grease. Some manufacturers recommend putting a thin layer of non-hardening sealing compound on the seal seat. Always install the seal with the lip pointing inward, or toward the fluid it will seal. Be careful when installing the hub assembly on the spindle not to damage the oil seal.

ADJUSTING BEARINGS

In most cases wheel bearing adjustment involves:

1. Tightening the bearing nut while rotating the wheel alternately in both directions, until a slight bind is felt. Four types of bearing nut arrangements are shown in Figure 6-404.
2. Backing off the nut a fraction of a turn to align with the nearest locking hole.
3. Locking the nut.

Below are two examples of adjusting procedures for grease or oil lubricated bearings taken from Timken service information.

1. **Single Adjusting Nut**

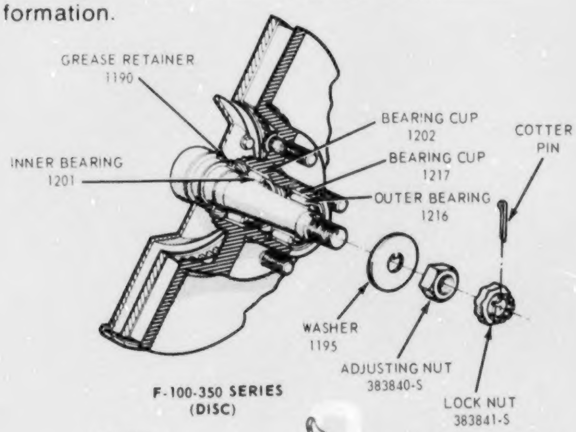
   Tighten the adjusting nut with a 12 inch wrench, while rotating the wheel, until there is a slight bind to be sure all bearing surfaces are in contact. Then back off adjusting nut one-sixth to one-quarter turn or to the nearest locking hole or sufficiently to allow the wheel to rotate freely within limits of .001 inch to .010 inch end play. Lock nut at this position.

2. **Double Adjusting Nuts**

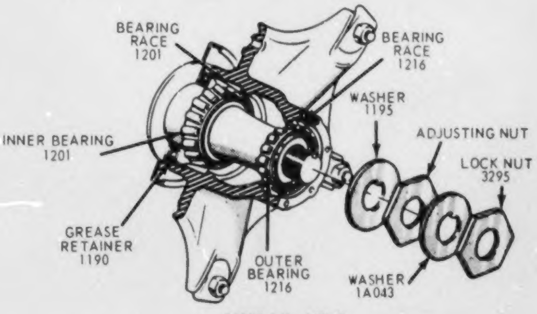
   Tighten inner nut with 12 inch wrench, while rotating the wheel, until there is a slight bind so that all bearing surfaces are in contact. Then back off inner nut one-quarter to one-third turn to allow the wheel to rotate freely. Install lockwasher. Tighten jam or outer nut. Final bearing adjustment should be wtihin .001 inch to .010 inch end play. Lock nut at this position.

Note the following two factors that can interfere with getting a correct bearing adjustment:

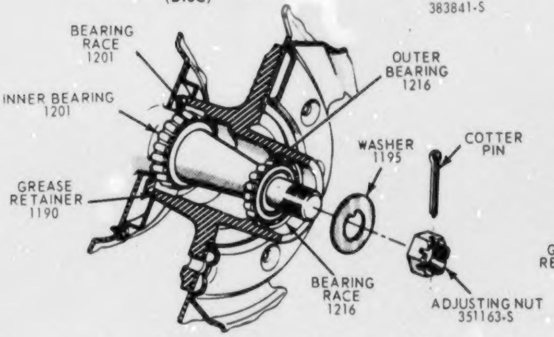
- — make certain that brake shoes aren't in contact with the drum because you will get a false adjustment.
- — do not confuse bearing tightness with a possible drag of the seal.


GREASE RETAINER
1190
INNER BEARING
1201
BEARING CUP
1202
BEARING CUP
1217
OUTER BEARING
1216
COTTER
PIN
WASHER
1195
ADJUSTING NUT
383840-S
LOCK NUT
383841-S

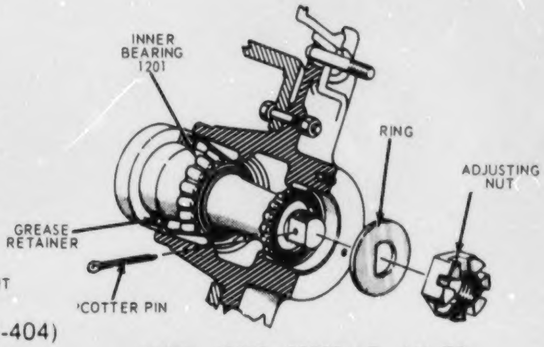
F-100-350 SERIES
(DISC)


BEARING
RACE
1201
BEARING
RACE
1216
WASHER
1195
ADJUSTING NUT
LOCK NUT
3295
INNER BEARING
1201
GREASE
RETAINER
1190
OUTER
BEARING
1216
WASHER
1A043

12000 LB. AXLE
(CENTER POINT)


BEARING
RACE
1201
INNER BEARING
1201
OUTER
BEARING
1216
WASHER
1195
COTTER
PIN
GREASE
RETAINER
1190
BEARING
RACE
1216
ADJUSTING NUT
351163-S

5000 - 5500 - 6000 - 7000 LB. AXLES (6-404)


INNER
BEARING
1201
RING
ADJUSTING
NUT
GREASE
RETAINER
COTTER PIN

16000, 18000, 20000 LB. AXLES

Courtesy of Ford Motor Company

Checking Wheel Bearings

The discussion on bearing adjustment above assumed that the bearings had been removed and were adjusted when reinstalled. Following is a quick method of checking bearings without removing anything: jack up the front axle until the wheels clear the floor. Check the bearing play by grasping the tire at the top and pulling back and forth, or by using a pry bar under the tire. If the bearings are properly adjusted, movement of the brake drum in relation to the backing plate will be barely noticeable and the wheel will turn freely. If the movement is excessive, adjust as above.

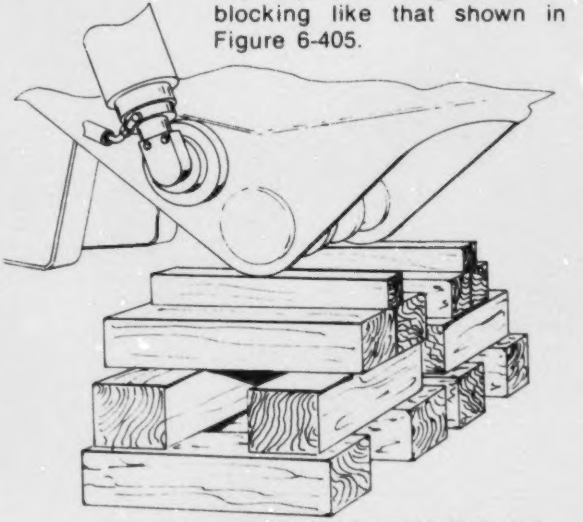
SERVICE REPAIR OF FRONT SUSPENSION AND STEERING

The job of removing, repairing and installing the front suspension and steering components of a wheel vehicle is similar to working on a crawler undercarriage in that the work is not highly technical but care must be taken when handling the heavy parts. Many front suspension components can be repaired or replaced without removing the whole suspension assembly. However, if the suspension requires a major overhaul, it is best to remove the complete assembly and work on it on the floor. The suspension service material given here assumes that a major repair is being undertaken.

Removing Front Suspension and Steering

1. It is a good practice to clean the steering and suspension parts outside the shop before bringing the vehicle inside to remove the assembly. If no cleaning equipment is available clean the parts individually as they are removed.
2. Block and jack the vehicle high enough so that the wheels clear the ground. A good place to block is on the frame just behind the rear of the front springs. The vehicle can also be raised with a chain hoist and suitable rigging or with an overhead crane.

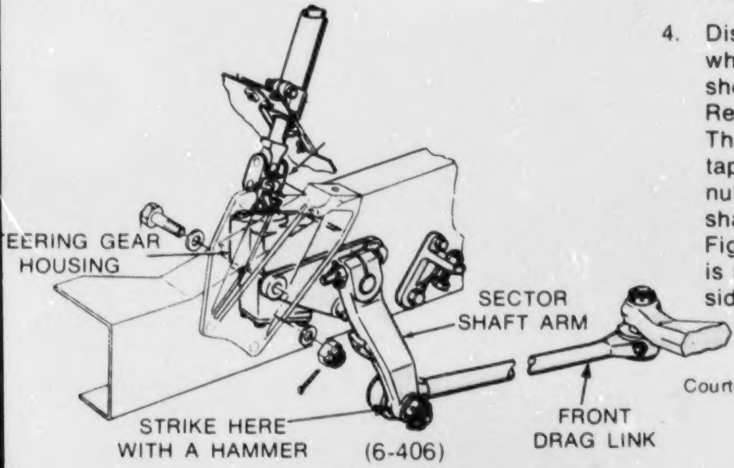
   Caution: Whatever lifting method is used, make sure that the device has adequate lifting capacity. Also, use good sound blocking like that shown in Figure 6-405.



(6-405) BLOCKING UNDER FRAME

Courtesy of Wabco Construction and Mining Equipment

3. Remove the wheels and hubs as an assembly. Take off the hub cap or bearing dust cover to gain access to the bearing retaining nut. Once the bearing retaining nut and outer bearing have been removed, use a suitable lifting device such as a wheel jack or forklift to lift the wheel-hub assembly clear.
4. Disconnect the brake lines and cap them, whether hydraulic or air. If the vehicle has shocks, disconnect them at the frame. Remove the drag link at the Pitman arm. The stud on the end of the drag link is a tapered fit into the Pitman arm. After the nut has been removed, strike the arm sharply with a hammer as indicated in Figure 6-406. Sometimes another hammer is required as a back up on the opposite side of the arm.



(6-406)

Courtesy of Ford Motor Company

5. Support the front axle and springs with suitable blocking or, even better, with two floor jacks. Remove the spring shackle pins and lower the spring axle assembly to the floor. Note: Make a punch mark on the front of the spring pad before removing the axle. If the axle center is not marked, it could be installed backward and the camber could be wrong.

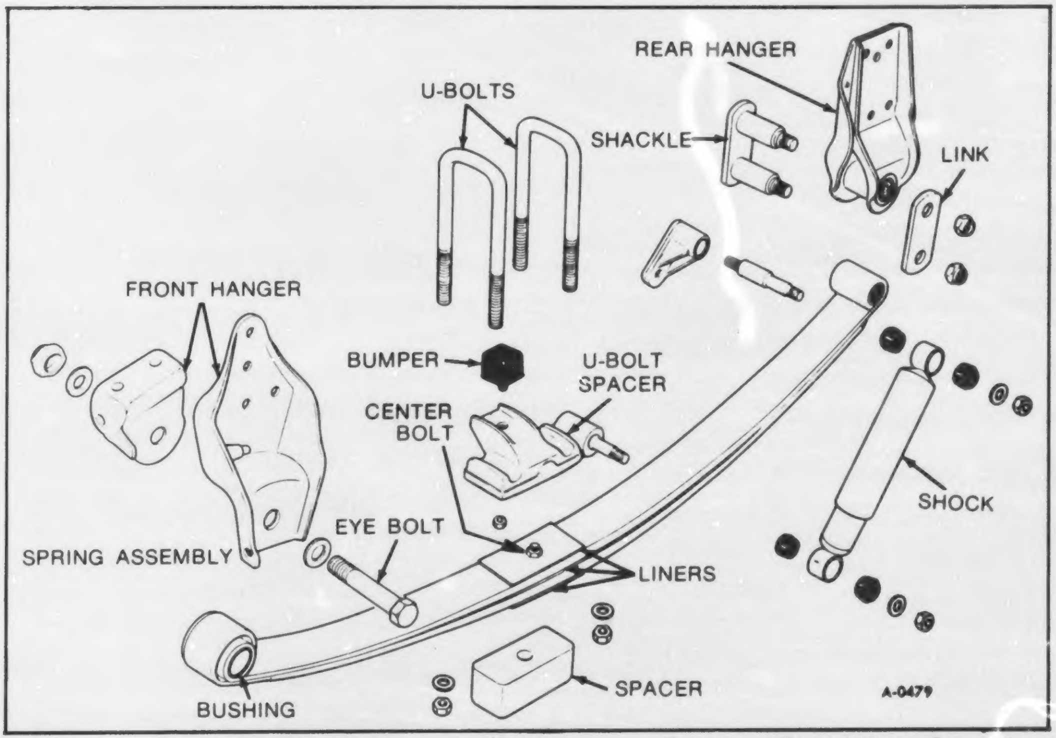
Repair Of Front Suspension and Steering

1. Once the axle and springs have been removed and taken out from under the vehicle, a careful inspection should be made of the spring hangers and their frame mounts. Tighten any loose bolts and replace any loose rivets. If the hanger brackets are damaged in any way, they should be replaced. The frame and cross members should also be carefully checked and any cracks must be repaired by a welder or competent journeyperson.
2. Remove the springs from the axles at the U-bolts. Note the position of shims, spacer blocks, shock brackets and dowel pins so that they can be correctly reinstalled. Springs become fatigued and flattened after long service. When doing a complete steering-front suspension overhaul, the general practice is to send the springs to a spring shop for rebuilding. Rebuilding a spring involves replacing all cracked or broken leaves and rearcing the serviceable leaves. New spring eye bushings and a new center bolt are put in. A rebuilt spring is virtually as good as a new one. Figure 6-407 shows a dismantled assembly.

Note the following when installing springs:

(a) Springs must be installed in the correct direction; i.e., the center bolt is often off center making the distance from the bolt to the spring eye longer one-way than the other.

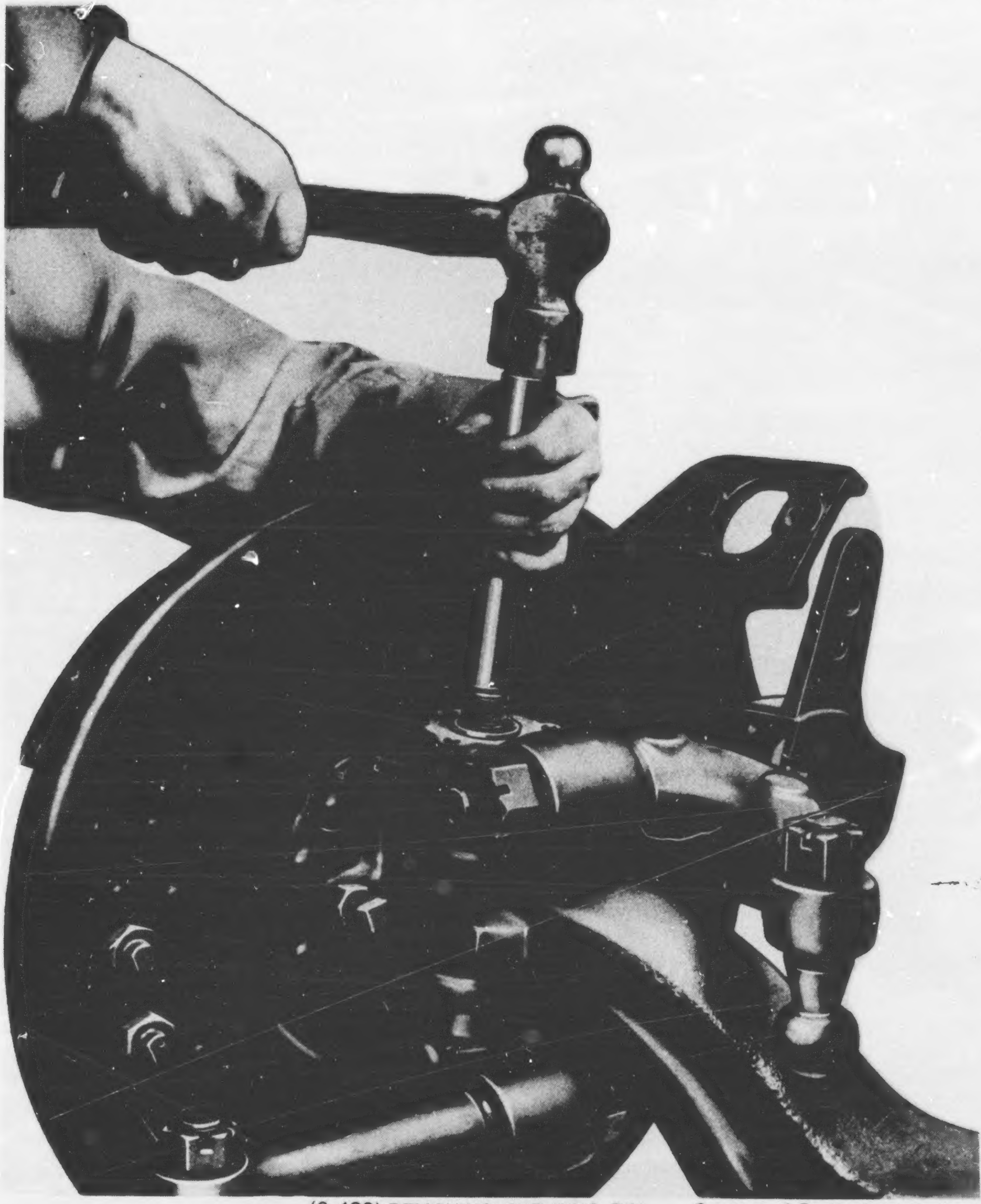
(b) If a spacer is used between the spring and the axle, be sure to insert the center bolt head through the hole in the spacer and into its slot in the axle. Similarly, if alignment shims (for caster) are used, install them in the correct direction and in their original position. Again, be sure that the center bolt fits through the hold in the shims and into its axle slot.



(6-407) Courtesy of General Motors Corporation

(c) Tighten U-bolts with a torque wrench to the specified torque listed in the service manuals.

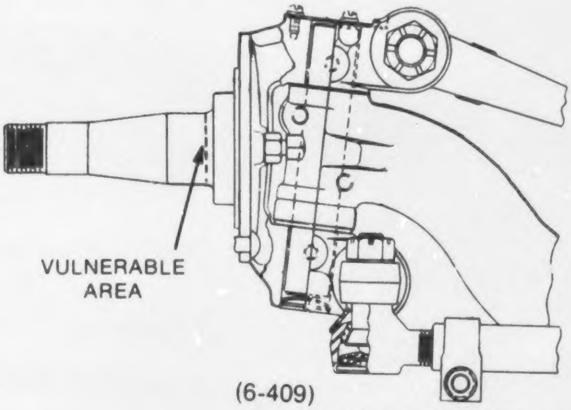
3. Repairs to the steering axle consists of removing the steering knuckles from the axle center and replacing the king pins and bushings. (See the service manual for procedures.) Figure 6-408 shows a king pin being removed with a hammer and drift. In some cases, however, a press may be required to remove the pin. Check the king pins by raising the wheel and moving it in and out at the top and bottom. If wheel play is excessive, it is an indication that the king pins are loose.



(6-408) REMOVING THE KING PIN

Courtesy of Rockwell International Automotive Operations

4. Small cracks may exist in steering parts. Since these parts are so vital to the safety of the vehicle, it is a good practice to have knuckles, spindles, steering arms and axle ends X-rayed or magnafluxed for defects. Some shops have the policy of automatically magnafluxing or X-raying vital steering parts. Spindles are the most vulnerable parts for cracking, especially at the point where they join the knuckle right near the seal surface (Figure 6-409).



(6-409)
Courtesy of Rockwell International Automotive Operations

If electronic crack detecting equipment is not available, cracks can sometimes be spotted in the following way: wash the spindle, and holding it in one hand strike it a few light blows with a hammer. If a crack exists, it will show up as a faint dark line. This method is not as reliable as a magnaflux or an X-ray, but it will detect cracks in many cases.

5. If a king pin is loose fitting in the axle eye, it must be repaired. The method of repair is to have the axle bored out at a machine shop and a steel bushing installed to return it to its original size. Prelube king pins (and shackle pins) before installing them.

When assembling the steering knuckle and axle, careful attention must be paid to correctly install the thrust bearing. Also the knuckle must have the correct clearance with the axle: there must be some clearance or end play at the axle knuckle connection between the yoke and the pin bore. Most manufacturer's recommend measuring the clearance with a dial indicator. Use of a dial indicator is described below:

(a) Set up the dial indicator as shown in Figure 6-410. This dial indicator has a magnetic base to attach it to the spindle. Other dial indicators can be affixed by a clamp.

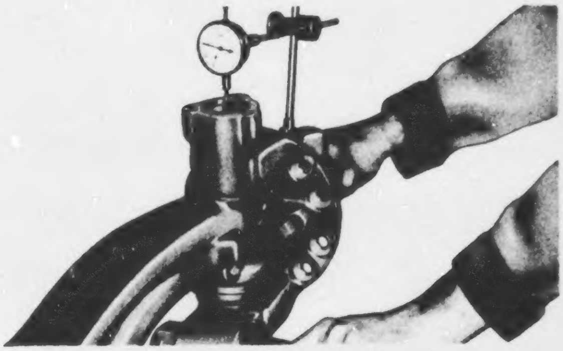
(b) Place the dial indicator plunger on the exposed end of the knuckle pin so its line of action is approximately parallel to the knuckle pin centerline.

(c) Zero the dial indicator.

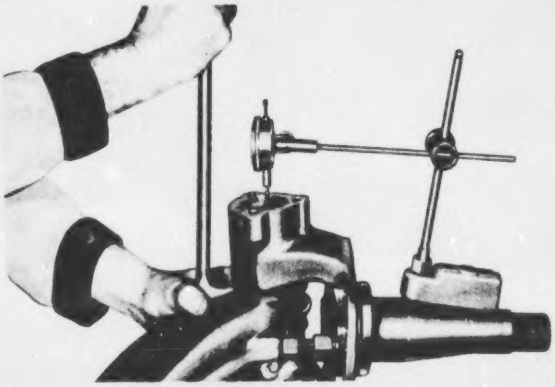
(d) Using a suitable lever or block and lever, lift the knuckle and take the dial reading.

(e) Repeat the above procedures with the knuckle in full right and full left turn positions.

(f) If the clearance is not right, correct it by adding or taking out shims between the axle and the knuckle.



(6-410) ZERO THE DIAL INDICATOR

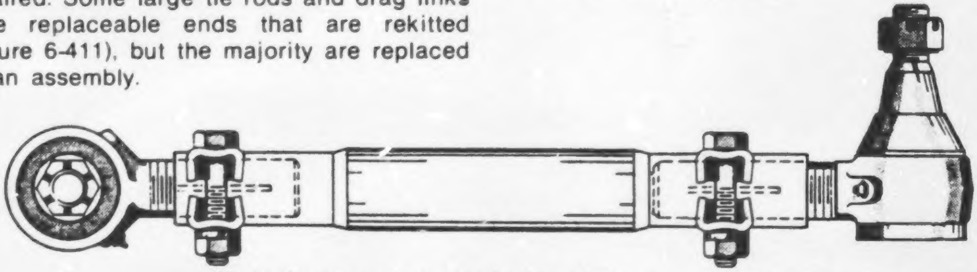


(6-410) PRY THE KNUCKLE AND TAKE READING

Courtesy of Rockwell International Automotive Operations

STEERING LINKAGE REPAIRS

When a complete overhaul is done on steering, linkage parts (tie rod, tie rod ends, drag link) should be carefully checked. If worn or faulty, they should be replaced, not repaired. Some large tie rods and drag links have replaceable ends that are rekitted (Figure 6-411), but the majority are replaced as an assembly.



(6-411) DRAG LINK ASSEMBLY WITH REPLACEABLE ENDS Courtesy of Kenworth Truck Company

Steering Alignment

Steering is aligned after an overhaul of the front end, or as the need arises. Before attempting an alignment, some pre-alignment checks should first be made. Note that some of the pre-alignment checks listed below won't apply to a vehicle that has just had the front end overhauled.

Pre-Alignment Checks (Move the vehicle to level ground)

1. Inflate the tires to the recommended pressure. Be sure that they are the same size and have the same number of plies.
2. Check for wheel and tire runout.
3. Check wheel balance.
4. Check that spring U-bolt nuts are tight.
5. Check for loose steering linkage or knuckle pin bushings or bearings.
6. Check the springs for sag or broken leaves.
7. Check wheel bearing adjustment.

Make any necessary repairs or replacements before proceeding with the alignment.

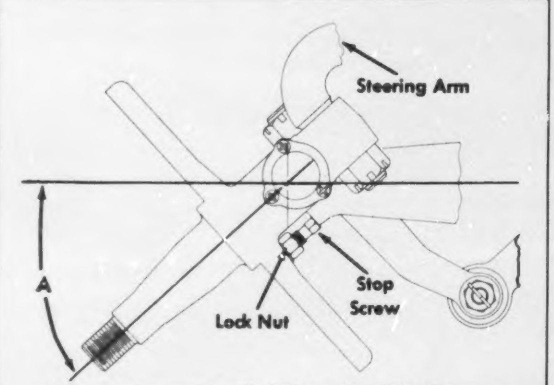
Alignment Checks

Easy, accurate steering depends on precise alignment of the front wheels. Alignment on heavy duty vehicles generally consists of getting the correct turning angle, caster and toe-in. The other alignment factors, camber, king pin inclination, and toe-out on turns, are considered non-adjustable. Camber can only be changed by bending the axle, and few shops are equipped to do this; K.P.I. is built into the axle design; and toe-out on turns is part of steering arm design. Problems in these three areas will require more extensive repair or replacement of parts.

Turning Angle

Check the turning angle first. The term turning angle denotes the maximum number of degrees, both left and right, that the front wheels can be turned from a straight-ahead position. Correct setting of this angle is important. Too large an angle will permit interference between the tire and chassis, which could damage the steering box. Too small an angle will reduce the truck's maneuverability. A 30° turn, both left and right, is standard on most non-driving front axles.

Turning angles should be checked whenever wheels are aligned or new front axle or springs are installed. Turning angles are adjusted by stop screws located either on the back of the steering knuckle, or on the axle as in Figure 6-412.



A—Dimension varies with different size tires. Set stop screws to provide ⅝" clearance between tires and chassis at extreme turn positions. TPM-7608

(6-412) STOP SCREW ADJUSTMENT
Courtesy of General Motors Corporation

The angles should be set with these factors in mind:

1. On extreme right or left turn there must be a clearance (recommendations vary from 1/2 inch to 1 inch) between the tires and the chassis or drag link.
2. There must be a minimum of 1/2 inch clearance between moving steering linkage and the chassis.
3. On vehicles with power steering, an additional step must be taken. The internal relief valves of integral power steering gears and the steering gear lever stops of linkage power-assist systems must be adjusted to cut off the power before the axle stops are contacted. Clearance between the knuckle and stop should be 1/16 to 1/8 inch when power is cut. Adjust for both right and left turns. See service manual for adjusting procedures.
4. For good steering performance, the steering gear should be centered when the wheels are in a straight-ahead position. If the gear is centered, it will not bottom when the front wheels are at maximum angle. The steering wheel should have one-third turn remaining when the front wheels are at the axle stops.

   To check steering gear centering, place the front wheels in a straight-ahead position, and then disconnect the drag link at one end. Turn the steering gear to its center position and try to reconnect the drag link. If the drag link can be reinstalled without disturbing the front wheels or steering gear, the system is satisfactorily centered. If the drag link ball stud does not line up with its mating hole, the system is not centered and corrections must be made. See the service manual for centering procedures.

Caster

As stated earlier, most trucks have a positive caster, i.e., the knuckle pin is tilted to the rear. The angle of tilt should not vary more than half a degree between the right and left side. Caster is adjusted by wedge shaped shims called caster plates located between the spring and the axle. Caster plates are factory installed. For positive caster the thick end of the shim faces the rear of the vehicle; for negative caster the thick end faces forward (see Figure 6-412). When servicing the springs and front axle of a vehicle equipped with caster plates, mark the position of the thick end before removing it to insure correct reassembly.

To check caster, the alignment equipment below is required (instruction will be supplied with the equipment):

- — Two turntables marked out in degrees to place underneath the tires.
- — A portable caster/camber gauge with a magnetic head for attaching to the end of the spindle. When a caster setting that varies greatly from the specified figure is found, check for problems in the front springs or axle. Weak or broken springs, in particular, can throw out caster. Replace defective front end parts before proceeding with the caster check. Do not attempt to correct severely misaligned caster by using an extreme angle caster plate. If it is necessary to change the caster setting, stay within the specifications recommended by the manufacturer.

Toe-In

Toe-in misalignment occurs when the wheels in the straight-ahead position are pointed inwards beyond an acceptable amount. (Many steering systems are set up to have a slight toe-in.) An obvious sign of excessive toe-in is a saw-toothed pattern across the face of the tire which can be felt by running your hand across the tire. (Toe-out will give an opposite saw-tooth pattern to toe-in.)

Measuring Toe-In

The method below is the most common and the most accurate way of measuring toe-in:

1. Raise the front wheels until they clear the floor.
2. Using the instrument shown in Figure 6-413, inscribe a fine line around the approximate center of each tire.
3. Lower the vehicle to the floor and turn the wheels straight-ahead (Note: Do not take a toe-in measurement with the front axle jacked up.)
4. Before taking a toe-in measurement, normalize the suspension parts by rolling the vehicle 12 to 15 feet ahead. This is necessary because when the vehicle is

first lowered, the tires grip the floor, preventing the wheels from returning to their normal operating position.

5. Measure the distance between these two scribed lines at the front of the tires and at the rear. The two measurements should be within allowable tolerances.

A quicker but less accurate method of measuring toe-in is to measure the distance between the tire tread centers or the insides of the tires, both at the front and back of the tires.

Correcting Toe-In

Before making a toe-in adjustment, the wheels must be normalized (see point 4, above).

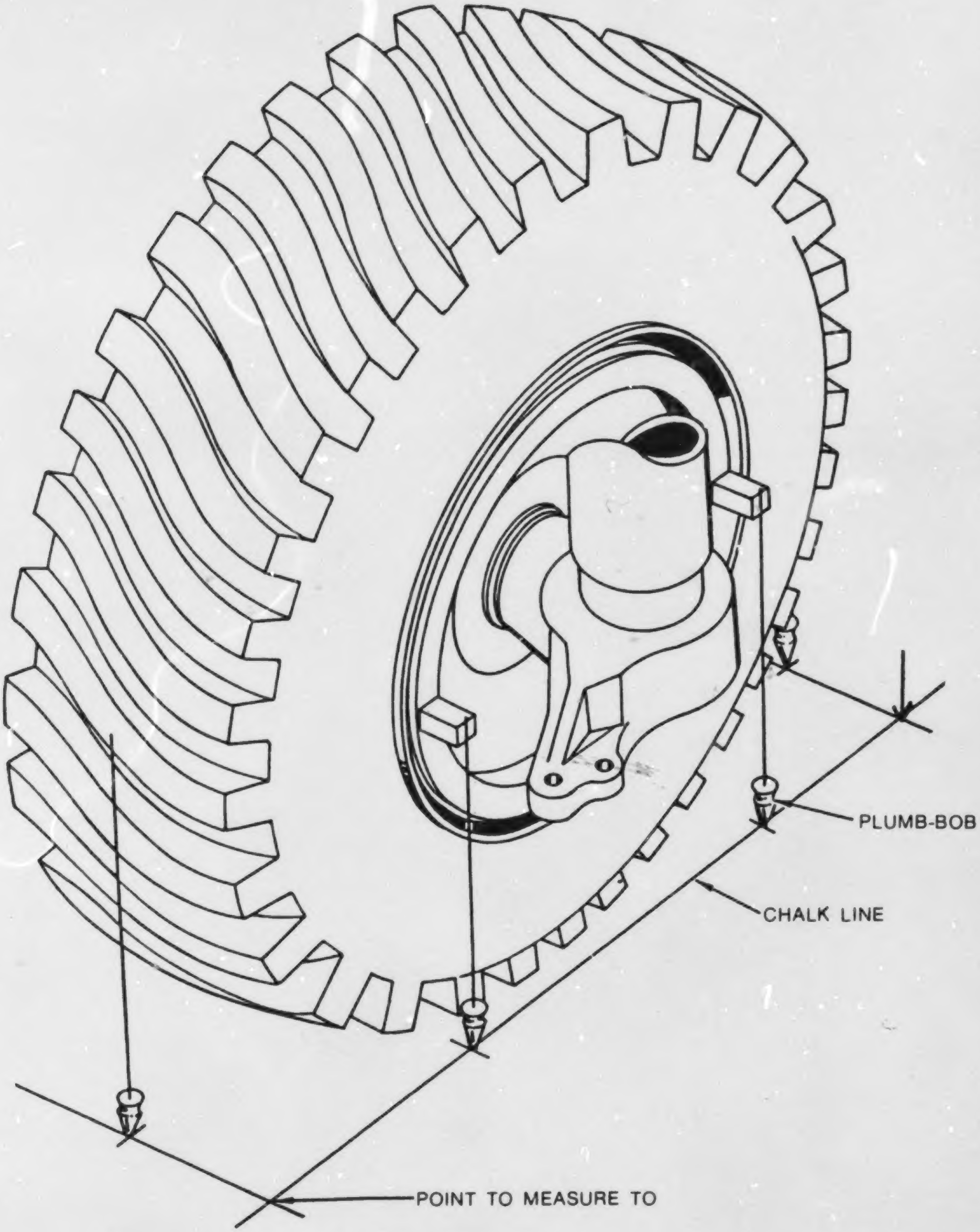
Minor toe-in corrections, on vehicles with straight cross steering tubes, are made by loosening the clamp bolts and turning the cross steering tube. The tube and ball sockets have either right and left hand threads or threads of different pitch. If the cross steering tube has a drop-center design, it generally is necessary to disconnect the tube and rotate the ball socket(s). If a major correction is required, first check for bent steering levers or a bent cross steering tube.

Toe-In On Large Mine Haulage Trucks

Toe-in is the only alignment procedure that is done on large mine haulage trucks. Below is the method one manufacturer recommends to measure toe-in. Refer to Figure 6-414.

1. Position the truck on a hard even surface with the front wheels straight-ahead. Adjust the front suspension cylinder to the recommended pressure and piston exposure.
2. Using a plumb-bob and a block (the block is used to provide an extension of the wheel hub surface), establish a point on the ground from both the front and rear of the wheel hub. Do this at each front wheel.
3. Using a chalk line, snap the line on the ground between these points. Extend the line out beyond the front and rear of the tire.
4. Drop a plumb-bob from the approximate front center of the tire and mark a point.
5. Drop a plumb-bob from the approximate rear center of tire and mark a point. Do this at both front wheels.
6. Measure the distance between the two lines at the front of the tires and at the rear. On this particular machine the distance at the front of the tires should be between half to one inch less than the distance at the rear of the tires. In other words, a toe-in of half to one inch is desired; anything over that should be corrected.

(6-413) Courtesy of Rockwell International Automotive Operations


PLUMB-BOB
CHALK LINE
POINT TO MEASURE TO

(6-414)

Courtesy of Wabco Construction
and Mining Company

Wheel Balancing

More attention is paid today than in the past to wheel balancing on heavy duty highway trucks. The reason is that trucks travel faster due to improved roads and tires. At the present time, very few heavy duty shops have wheel balancing equipment. When a balancing problem occurs, it is handled by a tire shop. This situation is changing, though, and no doubt in the future wheel balancing equipment will become as common in heavy duty shops as it is in automotive ones.

When faced with an assumed wheel balancing problem, you first should check some other likely possibilities that could be causing the problem. Check for:

- an out of round tire.
- excessive wheel or tire runout that could be caused by an improperly tightened or mounted wheel
- mud build-up on the inside of the wheel

As was mentioned earlier, dynamic wheel balancers are used to determine a wheel's state of balance. Two types are available, one for on-vehicle and one for off-vehicle balancing. Balancers indicate the location of heavy spots and in some cases give the amount of weight required to balance the wheel. If the balancer does not give the weight required, then a trial and error method is used to find the correct amount of balancing weight.

When a wheel balancer is not available, an unbalanced condition can be detected in the following way:

1. Jack the wheel up so that it clears the floor.
2. Back off the brake adjustment so that there is no interference from the brake shoes.
3. Adjust the wheel bearing so that the wheel will turn freely by itself.
4. Spin the wheel and allow it to come to rest. Chalk the tire at the bottom.
5. Repeat spinning the wheel. If the chalk mark continually appears at the bottom, a heavy spot is indicated at this point.
6. If wheel weights are at hand, you can get a reasonably close wheel balance setting. Select weights by trial and error placing them on the rim 180° from the heavy spot until the wheel has no tendency to stop at any given spot. When attaching weights to the rim, for example ten ounces, place five ounces, inside the rim and five ounces outside the rim. This method will even out the weight on the rim.

Note: Once the wheel has been balanced, don't forget to readjust the wheel bearing and brake.

Troubleshooting Steering

In the discussion above, steering was aligned as part of front end overhaul procedures. More commonly, a vehicle will come into a shop with what is vaguely referred to as a steering problem. When investigating a steering problem that has no evident cause(s), it is good diagnostic procedure to begin with the simplest possible cause. Then progress through to the more complex causes until the problem has been found. Check first for unequal tire pressures, loose wheel stud nuts, worn steering linkage, worn or dry king pins, loose or worn wheel bearings or a misaligned front end assembly. If these are in satisfactory condition, then isolate the steering gear for diagnosis by disconnecting both the drag link from the Pitman arm end and the steering column universal joint from the worm shaft. General steering gear problems and causes are listed below:

Problem: Hard Steering

1. Lack of lubricant (tight king pin).
2. Binding universal joints or slip joint.
3. Worm bearing or Pitman arm shaft adjusted too tight.
4. Worn steering gear bearings or bushings.
5. Worn or damaged worm gear or roller.
6. Binding cover boot in cab.

Problem: Wandering or Weaving

1. Excessive Pitman arm shaft backlash.
2. Loose steering gear mounting bolts.
3. Worn universal joints or slip joint spines.
4. Loose spring U-bolts.
5. Worn shackle pins and bushings.
6. Worn king pins.
7. Excessive toe-in or toe-out.
8. Worn tie rod ends.

Articulated Steering Repair

The steering repair on articulated machines that you will most likely be involved in at this level of training is servicing the center or hinge pin. Hydraulic repairs on articulated steering will be taken in future training. Repair of the hinge pin includes separating the two frame halves, cleaning and inspecting the hinge pin(s), bearings and seals, and replacing the worn or damaged parts. Also, the pin yokes on the frames should be checked for cracks. If any are found, they should be welded by a welder or jouneyperson.

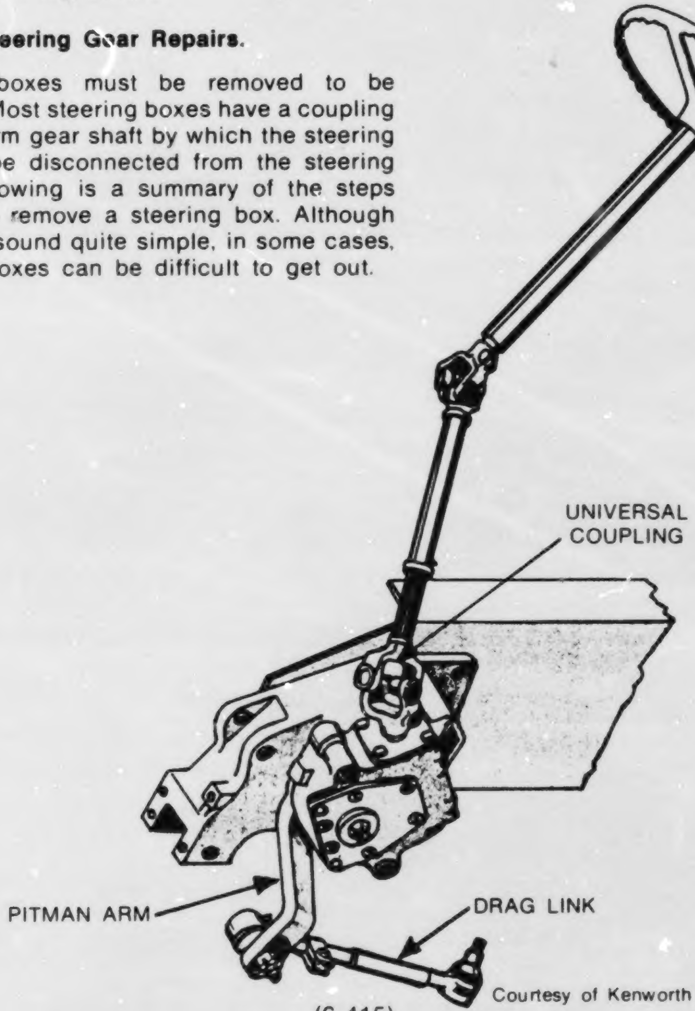
Note: Separating an articulated frame is a major job and requires correct lifting and blocking equipment. Refer to the service manual and obtain the help of a journeyperson.

Manual Steering Gear Repairs.

Steering boxes must be removed to be repaired. Most steering boxes have a coupling on the worm gear shaft by which the steering box can be disconnected from the steering shaft. Following is a summary of the steps needed to remove a steering box. Although the steps sound quite simple, in some cases, steering boxes can be difficult to get out.

To remove a typical manual steering box:

1. Turn the wheels to a straight-ahead position.
2. Disconnect the coupling on the steering shaft just above the gear box. Mark the coupling for reference with reassembling. The yoke may have a master spline but it is still a good idea to make a marking.
3. Remove the Pitman arm; this generally requires the use of a puller. Depending on the vehicle, it may be easier to first remove the drag link and then remove the Pitman arm after the box is out.
4. Remove the mounting bolts and lift the box clear of the frame. Figure 6-415 shows a typical example of manual steering mounting for a cab-over-engine truck:



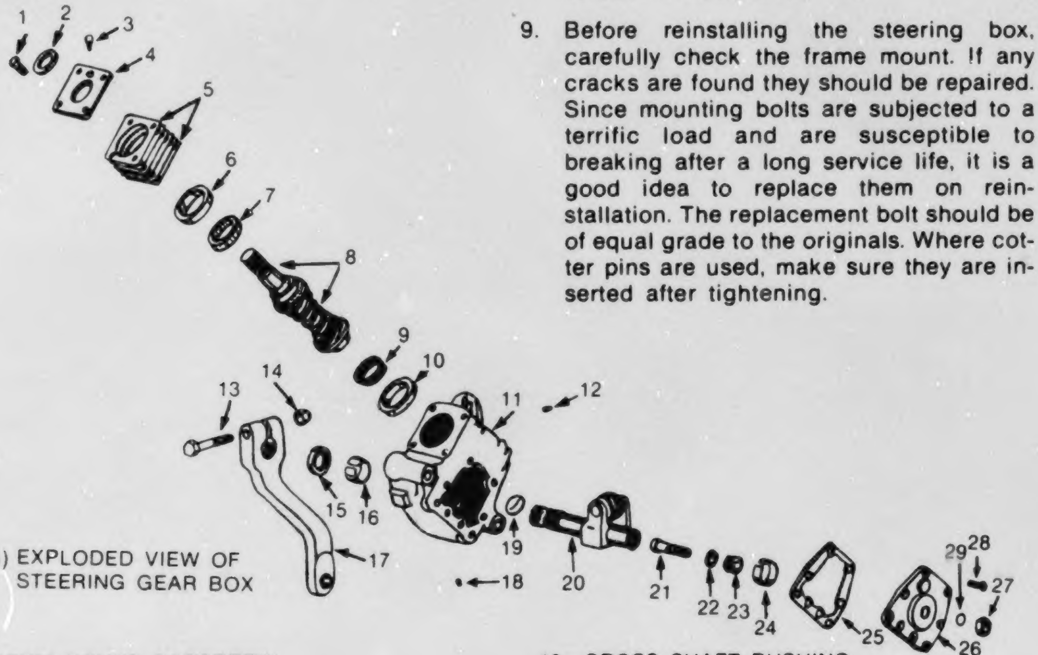
Courtesy of Kenworth Truck Company

(6-415)

Manual Steering Box Repair and Adjustment

1. In keeping with good repair practices, clean the exterior of the gear box with solvent before disassembling it, while cleaning the housing, inspect for cracks.
2. Drain the oil.
3. Disassemble as described in the service manual. Where applicable keep shim packs together as they will be needed for adjustment on reassembly.
4. Wash all internal parts and carefully inspect the gears for damage and wear.
5. Make parts list keeping in mind that these boxes work under heavy loads and therefore should automatically have the bearings, seals and cover gaskets replaced.
6. Pre-lube all parts and reassemble.
7. There are two adjustments to be made on a gear box:
   (a) worm shaft preload — adjusted by shims
   (b) sector shaft backlash — adjusted by adjusting screw.

   The worm shaft bearing preload is always done first and the sector shaft backlash second. Again follow the procedure in the service manual. In the exploded view of the steering box in Figure 6-416 note the shims (5) for worm shaft bearing preload adjustment and also the adjusting screw (21) for sector backlash adjustment.
8. Fill the box with the correct type and amount of lubricant.
9. Before reinstalling the steering box, carefully check the frame mount. If any cracks are found they should be repaired. Since mounting bolts are subjected to a terrific load and are susceptible to breaking after a long service life, it is a good idea to replace them on reinstallation. The replacement bolt should be of equal grade to the originals. Where cotter pins are used, make sure they are inserted after tightening.



(6-416) EXPLODED VIEW OF STEERING GEAR BOX

1	WORM COVER CAPSCREW
2	WORM SHAFT OIL SEAL
3	BREATHER
4	WORM COVER
5	WORM COVER SHIMS
6	WORM BEARING CUP
7	WORM BEARING CONE
8	WORM & SHAFT ASSEMBLY
9	WORM BEARING CONE
10	WORM BEARING CUP
11	HOUSING
12	OIL FILL PLUG
13	PITMAN ARM PINCH BOLT
14	PITMAN ARM PINCH BOLT NUT
15	CROSS SHAFT OIL SEAL
16	CROSS SHAFT BUSHING
17	PITMAN ARM
18	OIL DRAIN PLUG
19	EXPANSION PLUG
20	CROSS SHAFT ASSEMBLY
21	ADJUSTING SCREW
22	ADJUSTING SCREW THRUST WASHER
23	ADJUSTING SCREW RETAINER
24	CROSS SHAFT BUSHING
25	CROSS SHAFT COVER GASKET
26	CROSS SHAFT COVER
27	ADJUSTING SCREW LOCKNUT
28	CROSS SHAFT COVER CAPSCREW
29	CROSS SHAFT COVER O-RING

Courtesy of Kenworth Truck Co.

QUESTIONS WHEEL STEERING MAINTENANCE AND REPAIR

1. What on-the-machine adjustment is made to manual steering boxes?
   - (a) sector backlash, worm shaft preload
   - (b) worm shaft preload
   - (c) sector backlash
   - (d) adjustment of Pitman arm-drag link connection
2. List the three areas that steering lubrication is divided into.
3. Referring to Figure 6-400, what type of lubrication is used on tie rod ends, and how frequent, under normal operating conditions, should they be lubricated?
4. Wheel bearings are lubricated with either __________ or __________.
5. When packing wheel bearings with grease the hub between the two bearing cups:
   - (a) should be filled with grease
   - (b) should not have any grease in it
   - (c) should be filled with oil
   - (d) should be one-quarter filled with grease
6. A wheel bearing when properly adjusted should allow for:
   - (a) .001" to .010" preload
   - (b) .0" preload
   - (c) .001" to .010" end play
   - (d) .001" to .020" end play
7. When installing a wheel seal, the lip of the seal is placed with the lip pointing:
   - (a) inward
   - (b) outward
   - (c) either way; lip direction is not critical
8. A good service practice when brake or hydraulic lines are disconnected is to:
   - (a) tie the lines up out of the way
   - (b) cover the lines with a rag
   - (c) cap the ends of the lines
   - (d) remove the lines
9. If a spring has several cracked leaves, does good repair practice dictate that the spring must be replaced?
10. Where is the most likely place to check for a spindle crack?
11. If a king pin fits loosely in the axle eye, the recommended practice is to:
    - (a) replace the axle
    - (b) bore and re-bush the axle to its original size
    - (c) heat the axle and shrink it
    - (d) get a larger king pin
12. __________ is necessary at the axle-knuckle connection between the yoke and the pin bore. A __________ is used to measure it.
13. Besides setting the stop screws for maximum turning angle, the only other adjustments that are possible on a heavy duty truck front axle are:
    - (a) king pin inclination and camber
    - (b) caster and camber
    - (c) toe-out on turns and toe-in
    - (d) toe-in and caster
14. The most accurate method of adjusting a front wheel bearing is to:
    - (a) tighten the adjusting nut with a torque wrench to specification
    - (b) tighten the nut until the wheel drags, and then back off the nut a little
    - (c) make the nut finger tight
15. On a vehicle equipped with a solid I-beam front axle, an incorrect camber could be caused by:
    - (a) a bent spindle
    - (b) a bent axle
    - (c) both of the above
16. To check for worn king pins on a solid front axle:
    - (a) move the wheel in and out at the top and bottom
    - (b) move the wheel in and out at the front and rear
    - (c) move the wheel in and out on the centerline of the spindle

17. If a front wheel on a loaded truck has excessive negative camber, the:
    (a) outer wheel bearing has the greatest load
    (b) inner wheel bearing has the greatest load
    (c) both wheel bearings are loaded the same

18. If toe-out on turns is incorrect, the fault is:
    (a) an incorrect caster angle
    (b) incorrect toe-in
    (c) an incorrect camber angle
    (d) a bent steering arm(s)

19. If toe-in on a vehicle is incorrect, an obvious sign would be:
    (a) a wavy tire tread pattern
    (b) pulling to the left
    (c) a saw toothed pattern across the tire face
    (d) all the above would indicate a toe-in problem

20. A vehicle has been jacked to work on the front end and is lowered to the ground. What must be done before a toe-in measurement can be taken?

21. Vehicles with radial tires should have the toe-in set at:
    (a) 1/16″ toe-in
    (b) 1/8″ toe-in
    (c) 1/16″ toe-out
    (d) 0″ toe-in

22. Tires that are unbalanced and have been used for a long time will have:
    (a) feathered edges
    (b) cupping
    (c) tread worn off on the inside or outside of the tire
    (d) a wavy tread surface

23. When faced with what looks like an unbalanced wheel, what checks should be made first that could be causing the unbalanced wheel symptoms.

24. What would be the effect on steering of worn shackle pins and bushings, king pins, or tie rod ends?

25. When installing a rebuilt steering box, it is a recommended practice with mounting bolts to:
    (a) carefully check the bolts for cracks and replace the faulty ones
    (b) reuse the bolts as they almost never get damaged
    (c) replace all the bolts with new ones of equal grade to the originals

ANSWERS — WHEEL VEHICLE STEERING

1. (c) linear motion of the linkage
2. (d) tie rod
3. (d) Pitman arm to the steering control arm
4. — manual steering
   — power steering
   — emergency steering
5. — worm and roller
   — recirculating ball
   — cam and lever
6. False
7. . . . . hourglass. . . . straight.
8. (c) a lever and stud arrangement instead of gear
9. To allow the spring to lengthen and shorten as it flexes.
10. . . . . grease fittings.
11. (b) center bolt.
12. (c) control spring oscillations
13. True.
14. (b) The bottom of the axle eye
15. The flange on the wheel spindle.
16. Yes, two fittings. One each at the upper and lower pin bosses.
17. Grader wheels must tilt as well as turn.
18. . . . hydraulic tilt cylinder . . .
19. (d) all of the above are correct.
20. — power-assist
    — full power
    — hydrostatic
21. The booster can be either:
    (a) mounted to the front axle with the piston rod clamped to the tie rod
    (b) mounted within the drag link along with the control valve
22. (d) steering linkage (drag link)
23. . . . . integral power steering . . .
24. (b) steering box
25. The hydrostatic system has no mechanical connection between the steering wheel and the vehicle's wheel.
26. Depending on which way the steering wheel is turned, the steering unit directs oil to either the right or left steering cylinder which supplies the force to turn the wheels.
27. False.
28. To provide enough power to safely bring the vehicle to a stop. The three emergency systems are: orbital control, electric motor driven pump, hydraulic accumulator.
29. Steering geometry refers to the angular relationship between the front wheels, steering linkage and frame.
30. (c) forward or backward tilt of the king pin
31. positive caster.
32. True.
33. (b) an angle in the axle that tilts the top of the wheels outward.
34. True.
35. (b) positive camber
36. (a) cannot be adjusted without bending the axle
37. (d) adjusting the length of the tie rod
38. True.
39. (d) bring the steering pivot axis nearer the center of the tire-road contact area
40. . . . unbalanced . . . .
41. . . . . heavy spots. . . . vibrates. . . .
42. Kinetic unbalance that causes an up and down wheel motion or wheel tramp.
43. (c) 180° from the heavy spot.

ANSWERS — WHEEL STEERING MAINTENANCE AND REPAIR

1. (c) sector backlash

2. — steering linkage
   — manual steering gears
   — power steering systems

3. Chassis lube grease every 6,000 miles or 10,000 kilometers.

4. . . . grease or oil.

5. (d) should be one-quarter filled with grease

6. (c) .001" to .010" end play

7. (a) inward

8. (c) cap the ends of the lines

9. No. Springs can be rebuilt. A rebuilt spring can be almost as good as a new one. The cost is the main factor.

10. Where the spindle joins the knuckle flange near the seal surface.

11. (b) bore and rebush the axle to its original size

12. End play . . . . A dial indicator . . .

13. (d) toe-in and caster

14. (b) tighten the nut until the wheel drags, and then back off the nut a little

15. (c) both of the above

16. (a) move the wheel in and out at the top and bottom

17. (a) outer wheel bearing has the greatest load

18. (d) a bent steering arm(s)

19. (c) a saw toothed pattern across the tire face

20. Normalize the wheels by moving the vehicle forward and backward 10 to 15 feet.

21. (d) 0" toe-in

22. (d) a wavy tread surface

23. — out of round tire
    — excessive wheel run-out
    — mud accumulation on the inside of the wheel

24. Wandering or weaving steering.

25. (c) replace all the bolts with new ones of equal grade to the originals.

TASKS — WHEEL MACHINE STEERING AND FRONT SUSPENSION

ROUTINE MAINTENANCE CHECKS

1. Check for and tighten all loose suspension mountings. Retorque U-bolts. Check for cracked or broken spring leaves. Check all steering knuckles and linkages for worn or bent parts. Check shackle pins and bushings and king pins for wear. Check the frame, frame brackets, cross members and hangers for cracks and loose rivets. If the vehicle has hydraulic steering, check the cylinders and lines for leaks or damage. Do any minor repairs: report any major repairs needed.

SCHEDULED MAINTENANCE CHECK

1. Follow the service manual scheduled maintenance procedures for wheel vehicle steering and suspension to include the following:
   (a) Remove the wheel assembly, clean and repack the wheel bearings, replace seals and reinstall and adjust the bearings to manufacturer's specifications.
   (b) Move the vehicle to a level floor area and using what alignment tools and equipment are available, check and adjust the wheel alignment.
   (c) If the vehicle has hydro-air suspension, check for any signs of leaks or damage, and retorque mounting bolts. With the assistance of a journeyperson, check for proper piston extension and pressure, and adjust if needed.

SERVICE REPAIR

1. Jack a loader, truck (on-highway or off-highway), or grader, and block it securely at a height that permits removal of the steering and suspension components.
2. Using the correct tools, lifting equipment and procedures outlined in the service manual:
   (a) Clean and remove the steering axle, related steering components, and brake lines (if applicable).
      — if the vehicle has hydro-air suspension, bleed down the gas charge before removing the suspension cylinders.
      — if the vehicle has hydraulic steering, disconnect and cap the hydraulic lines connected to the steering axle.
      — if the vehicle has hydraulic brakes, disconnect and cap the hydraulic lines connected to the steering axle. If the vehicle has an oil over oil brake system, bleed down the pressure before removing the lines.
   (b) Clean, disassemble (where applicable), inspect and decide if the following parts are serviceable or if they must be repaired or replaced: springs, spring shackles, king pins, tie rod ends, drag links, pivot end bushings, related linkages hydraulic lines and hoses. Write a parts list. Repair or replace any parts that are not serviceable.
   (c) Check the frame cross members, frame brackets, and spring hangers for wear, cracks, loose bolts or rivets. Make the necessary repairs or replacements.
   (d) Prelubricate, and reassemble the suspension components.
   (e) Install the steering axle, suspension components, and brake lines (if applicable). Lower the vehicle:
      — if the vehicle has hydro-air suspension, under the supervision of a journeyperson, charge the cylinders to the specified pressure and suspension height.
      — if the vehicle has hydraulic steering, top up the reservoir with the correct type and amount of oil. Start the engine, turn the wheels full left and then full right to purge the air. Recheck the reservoir making sure that there are no leaks.
      — if the vehicle has hydraulic brakes, top up the reservoir with the correct type and amount of fluid. Bleed the system at the wheels to purge the air. Recheck the reservoir level, topping up if necessary, and test the brakes.

(f) Move the vehicle to a level floor area and, using what tools and equipment are available, align the suspension to obtain correct caster and toe-in settings. Recheck the complete suspension to ensure all components are secure and locking devices are installed. Lubricate all components where required.

3. Using the correct tools, and procedures outlined in the service manuals:

   (a) Remove a wheel machine manual steering box.

   (b) Clean, disassemble, inspect the gears and bearings for wear and damage. Write a parts list, and repair or replace any bearings or gears that are not serviceable.

   (c) Prelubricate, reassemble the gears and bearings, and make adjustments. Fill the housing with the correct type and amount of lubricant.

   (d) Check the frame mounting for cracks or damage and make any necessary repairs.

   (e) Reinstall the steering box, ensuring that all components are secure and locking devices are installed.

   (f) Road test the vehicle to check steering response and handling and make any final on-vehicle adjustments.

BLOCK

6

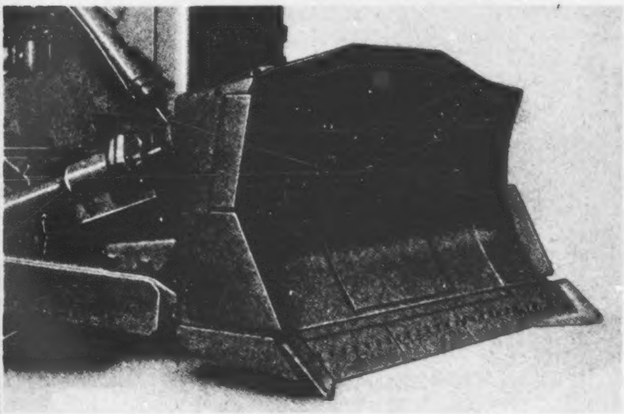
Working Attachments

DEFINITION

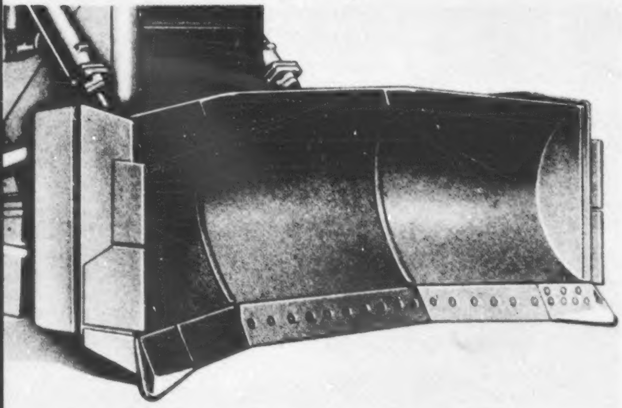
Working attachments are the implements that do a machine's work. Several types of implements can be used on the same machine. For example, the bucket on a wheel loader can be removed and replaced with log forks. This section discusses the working attachments available for common heavy duty machines.

CRAWLER DOZERS

A number of blades are available for dozers, each suited to a different type of job. Four common ones are shown in Figure 6-417. Universal and cushion blades are generally only used on large machines. Specialty attachments are also available for dozers such as the wood chip bucket in Figure 6-418 and the land clearing rake in Figure 6-419.

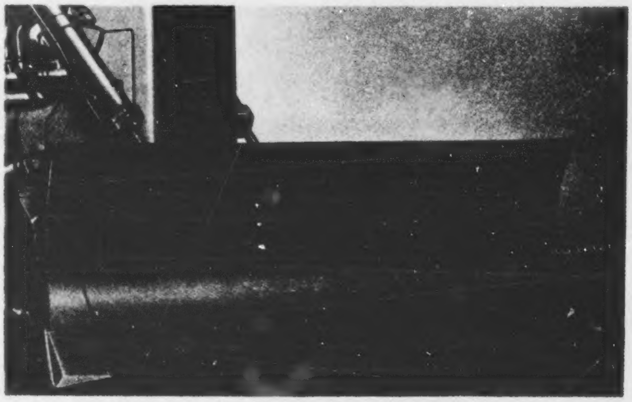


STRAIGHT BLADE — FOR GENERAL DOZING WHERE MATERIAL DRIFTED OVER A SHORT TO MEDIUM PASS. (6-417)

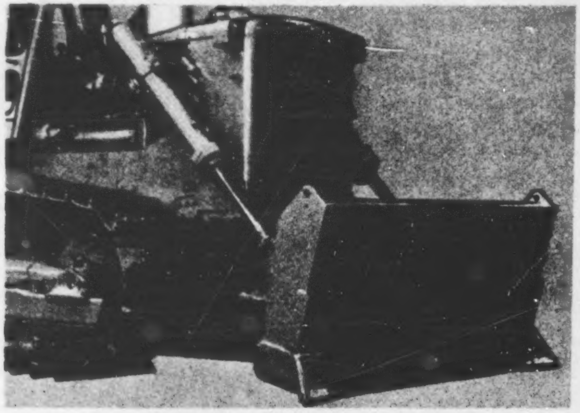


UNIVERSAL BLADE — MOVES LARGE VOLUME LOADS OVER LONG DISTANCES. BLADE DESIGN DIRECTS MATERIAL FORWARD AND TOWARD THE CENTER IN A CUPPING ACTION.

(6-417)



ANGLE BLADE — FOR PIONEERING, BACK-FILLING, WINDROWING, THIS MULTI-PURPOSE TOOL ANGLES 25° TO EITHER SIDE. GREATER MOLDBOARD CURVATURE GIVES MORE ROLLING ACTION. (6-417)



CUSHION BLADE — FOR PUSH SCRAPERS. SHOCK ABSORBING FEATURE PERMITS EASY, ON-THE-GO CONTACT. BLADE CAN ALSO BE USED FOR CLEAN-UP AND GENERAL WORK.

(6-417)

Courtesy of Caterpillar Tractor Co.

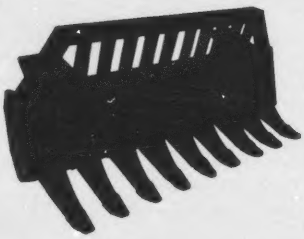
When selecting a blade, tractor size and the type of material that the dozer will cut and move must be considered. The weight and horsepower output of a tractor determine the blades ability to bulldoze materials. An indication of a blade's ability to penetrate and obtain a blade load is horsepower per foot of cutting edge (HP/ft). The higher the HP/ft., the more aggressive the blade. Similarly, an indication of a blades potential to push material is horsepower per loose cubic yard (HP/LCY). The higher the HP/LCP, the better and faster the blade can push material.

Below are characteristics of materials that influences the ease or difficulty with which they can be dozed.

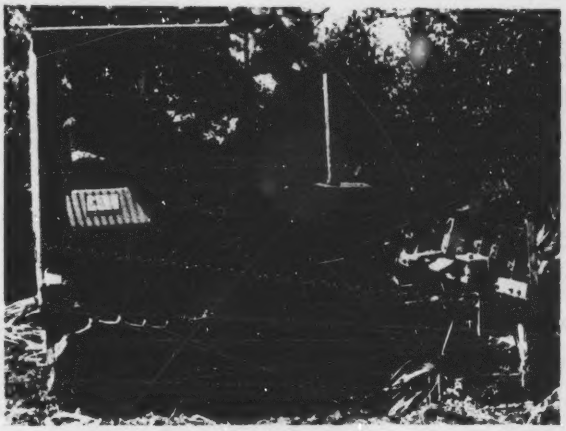
Material Size and Shape — The larger the individual particle size of the material, the more difficult it is for the blade's cutting edge to penetrate it. The shape of the material is important in moving the material: material particles with sharp edges resist the natural rolling action of a dozer blade, and therefore require more horsepower to move than material with rounded edges.

Material State (i.e., how tightly is it packed) — Well graded or packed material is generally harder to doze than loose packed material.

Material Water Content — Low moisture content usually increases the bond between particles, making the material difficult to cut. High moisture content makes the material heavy and hard to push. Optimum moisture content reduces dust and offers the best condition for dozing ease and operator comfort.

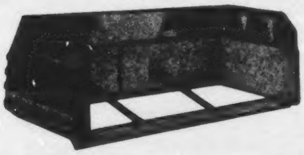


Clearing Rakes remove trees, rocks, and stumps, pile brush and generally prepare land for replanting. Rakes are made for all sizes of crawlers.

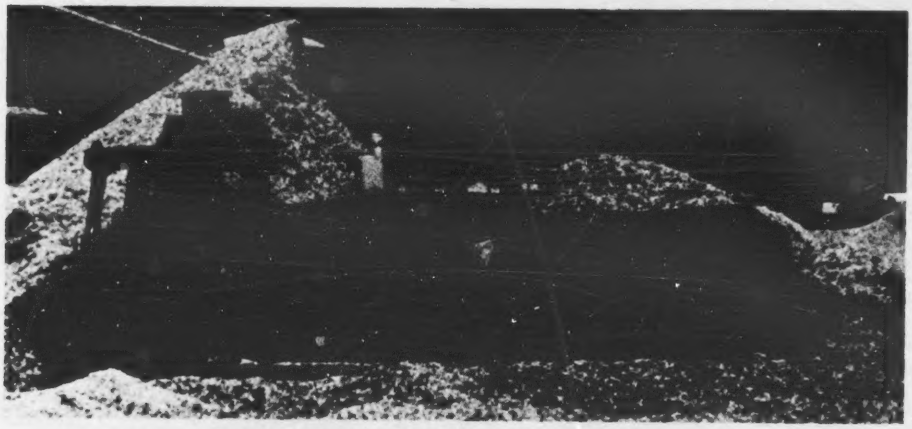


(6-419)

Courtesy of Caterpillar Tractor Co.



Wood Chip Blades handle volume loads. Bowl-type and U-type are available.



Wood Chip Bowls feature high sidewalls to move large volumes of light materials over long distances . . . up to 65 cu. yd. (50 m^3) heaped capacities.

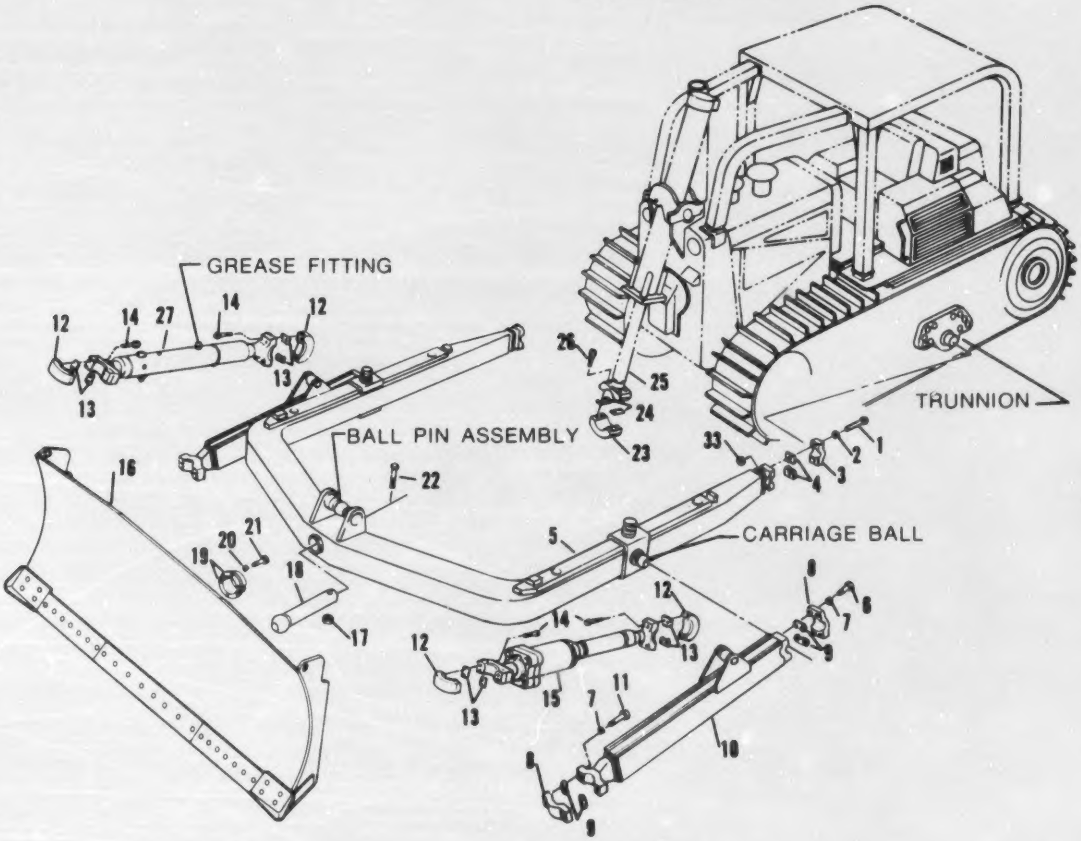
(6-418)

Courtesy of Caterpillar Tractor Co.

Crawler Blades

Crawler blades are made of heat treated, high tension strength steel and are constructed in box section. Replaceable hardened steel cutting edges are bolted to the bottom edge of the blade as are replaceable corner bits to the lower outside corners. Blades are raised and lowered by one, or more commonly two, hydraulic cylinders.

Blades can be mounted either on push beams, or on a C-frame as in Figure 6-420. The C-frame is more common. The ends of the C-frame are attached to trunnions on the track roller frame in this example. This frame and blade are raised and lowered by a hydraulic cylinder (25), and hydraulic tilt struts (27, 15) tilt the blade. Other machines have different tilt arrangements: some have only one tilt cylinder, while others have mechanical tilt struts. Two other points to note in the blade mounting in Figure 6-420 are: the blade is mounted at its center on a ball stud (18) assembly which allows the blade to swivel. Thrust channels (10) at each side of the C-frame are attached to the blade ends. They are adjustable in length permitting the blade to be angled left or right, or held in a straight-ahead position.



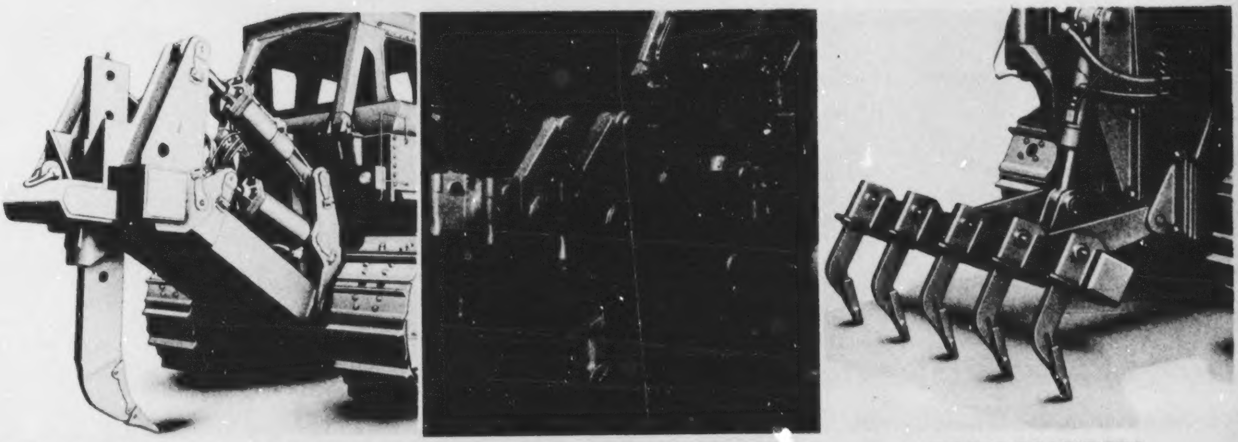
1	Bolts	10	Thrust Channels	19	Ball Sockets
2	Lockwashers	11	Bolts	20	Lockwashers
3	Caps	12	Caps	21	Bolts
4	Shims	13	Shims	22	Bolt
5	C-Frame	14	Bolts	23	Cap
6	Bolts	15	Tilt Strut Cylinder	24	Shims
7	Lockwashers	16	Angle Blade	25	Blade Cylinder
8	Caps	17	Nuts	26	Bolts
9	Shims	18	Ball Stud	27	Tilt Jack

(6-420) Courtesy of Caterpillar Tractor Co.

Crawler Attachments

A variety of rear-mounted attachments are also available for crawler dozers. Winches are often mounted on the rear of dozers for winching or towing (Figure 6-421). (Winches are dealt with in detail in Block 9.) Scarifiers or rippers can also be mounted on the rear of a dozer, their purpose to loosen the ground for easier dozing (Figure 6-422).

(6-421) TRACTOR-MOUNTED WINCH Courtesy of Caterpillar Tractor Co.



SINGLE-SHANK ADJUSTABLE RIPPER

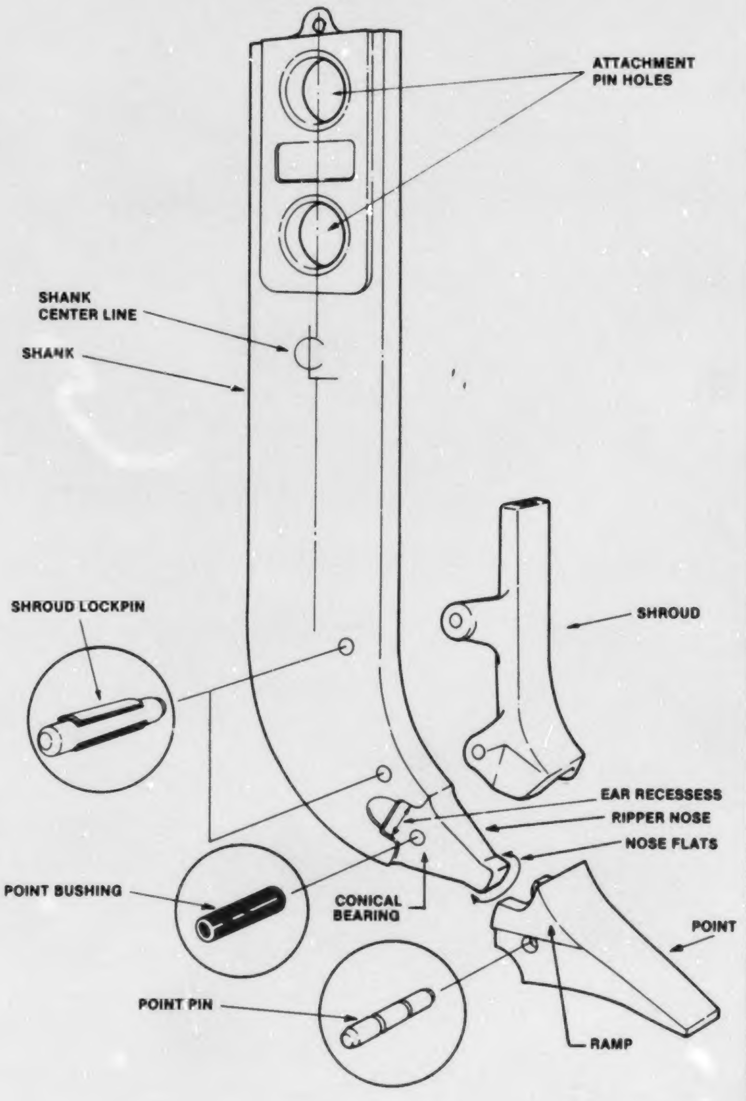
D7 MULTISHANK RIPPER

RIPPER-SCARIFIERS

(6-422)

Courtesy of Caterpillar Tractor Co.

Figure 6-423 shows a detail of a ripper. A ripper consists of three basic parts: a shank, wear shroud, and tooth or point. Both the tooth and the shroud are replaceable wear parts.

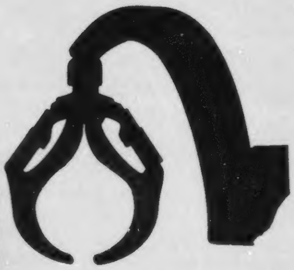


Ripper Nomenclature Guide

ATTACHMENT PIN HOLES
SHANK CENTER LINE
SHANK
SHROUD LOCKPIN
SHROUD
EAR RECESSESS
RIPPER NOSE
NOSE FLATS
POINT BUSHING
CONICAL BEARING
POINT
POINT PIN
RAMP

(6-423) Courtesy of Esco Corporation

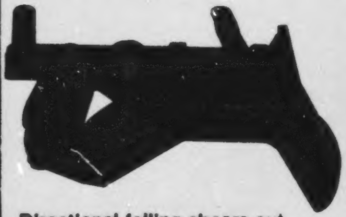
Crawlers working the logging industry use special attachments, e.g., skidding grapples (Figure 6-424), directional felling shears (Figure 6-425) and a winch arch (Figure 6-426).



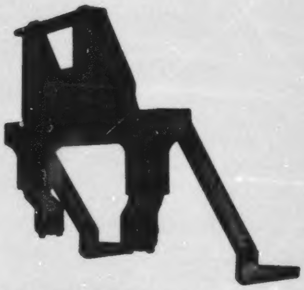
Hydraulic skidding grapples

(6-424) Courtesy of Caterpillar Tractor Co.

(6-425) Courtesy of Caterpillar Tractor Co.



Directional felling shears cut trees up to 30" (762 mm) diameter at ground level. Trees can be felled with butt ends aligned to aid skidding.



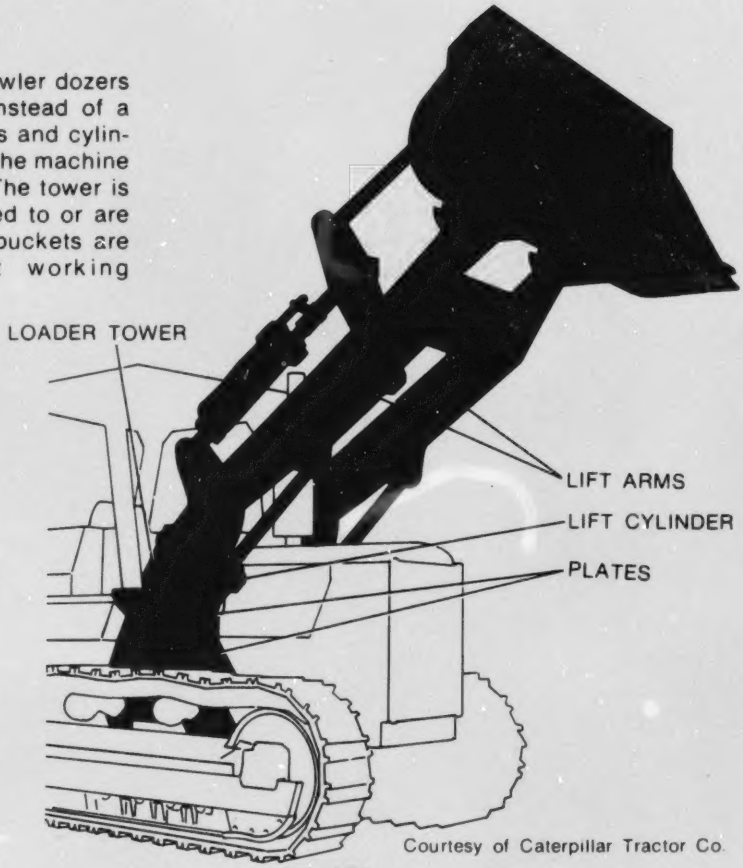
Integral arch protects the winch case, reduces ground disturbance and helps keep logs clean when cable skidding.

(6-426)

Courtesy of Caterpillar Tractor Co.

CRAWLER LOADERS

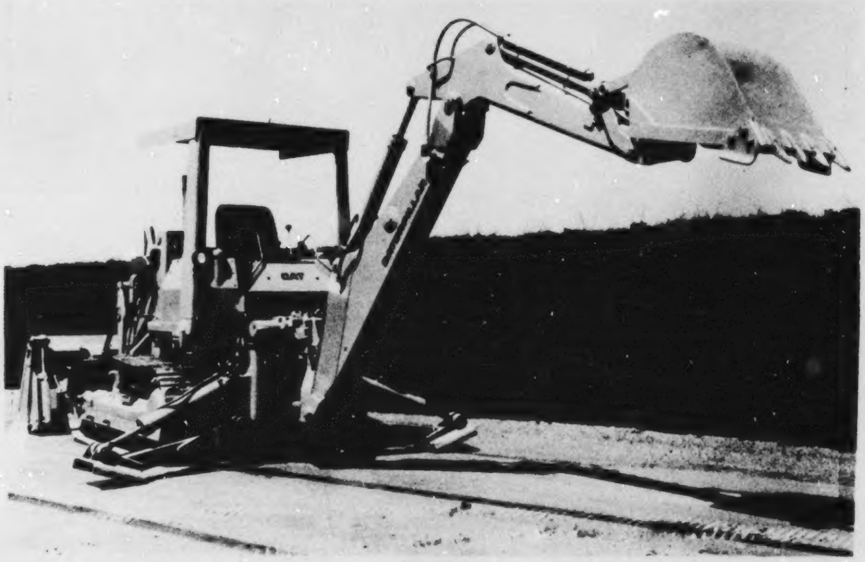
Crawler loaders are similar to crawler dozers except that they use a bucket instead of a blade. The loader bucket, lift arms and cylinders are attached on each side of the machine to a loader tower (Figure 6-427). The tower is made of plates which are attached to or are part of the main frame. Various buckets are available to meet different working requirements.



Courtesy of Caterpillar Tractor Co.

(6-427)

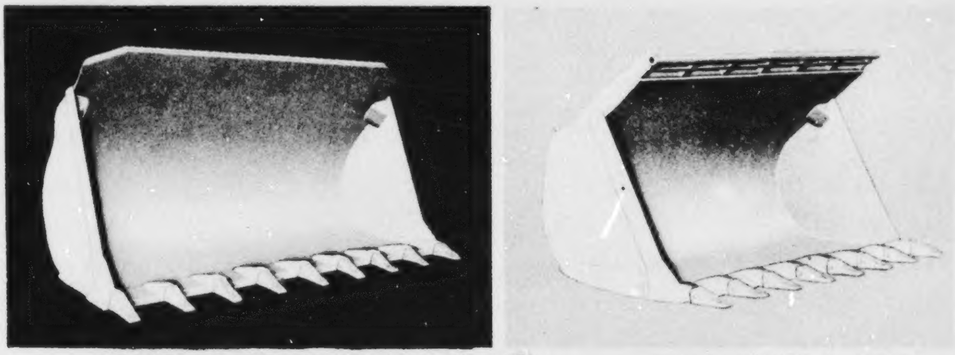
A combination quite often used on crawler loaders is to have a bucket in front and a backhoe on the rear (Figure 6-428). This combination gives a very versatile machine.



(6-428) Courtesy of Caterpillar Tractor Co.

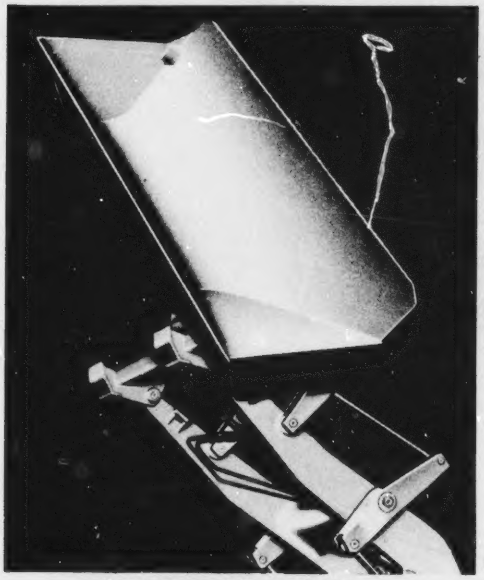
WHEEL LOADERS

Various types of buckets are available for wheel loaders. General purpose buckets and rock buckets (Figure 6-429) are the most common. Some specialty buckets are a side dump bucket (Figure 6-430), a multi-purpose bucket (Figure 6-430), and a bucket that could be used for such materials as chips or snow (Figure 6-431).



GENERAL PURPOSE BUCKET (6-429) ROCK BUCKET

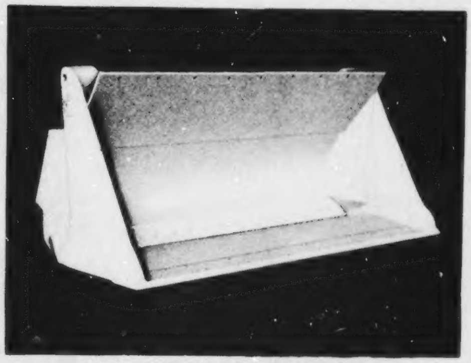
Courtesy of Caterpillar Tractor Co.



SIDE DUMP BUCKET

Dumps forward or to the left. For close quarter work.

(6-430)

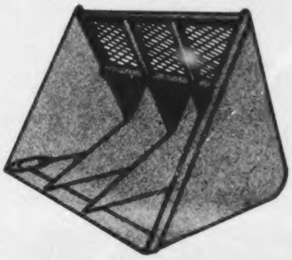


MULTI-PURPOSE BUCKET

Can load and strip top soil. The bucket clamps hydraulically to grip logs, pipes and other hard to grasp material.

(6-430)

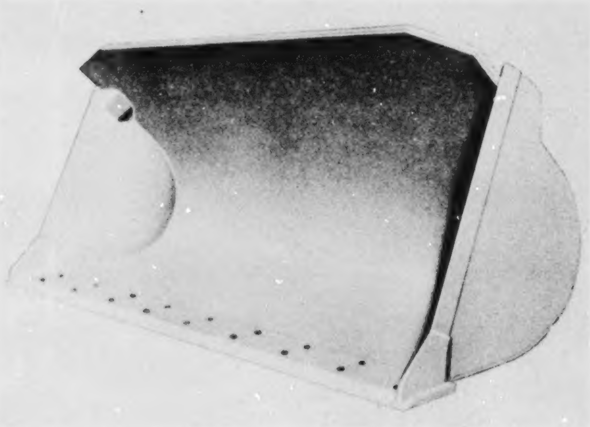
Courtesy of Caterpillar Tractor Co.



(6-431) SNOW, CHIP BUCKET

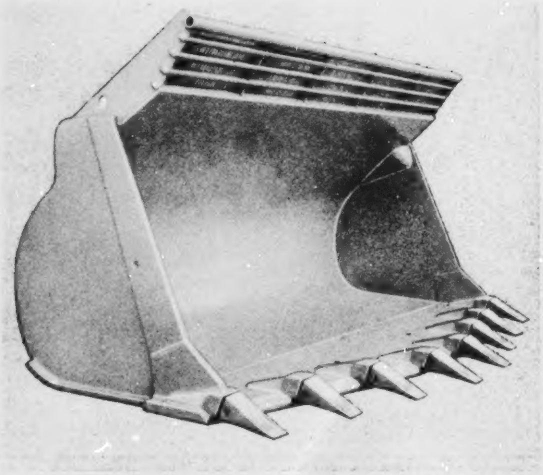
Courtesy of Caterpillar Tractor Co.

Buckets, like blades, also need protection on their lower edge and corners. Common parts used to protect buckets are cutting edges, wear strips, and bucket teeth. All of these parts are replaceable. Figure 6-433 and 6-434 give detailed views of bucket teeth, wear plates and cutting edges.



BUCKET WITH CUTTING EDGE AND WEAR STRIP BOLTED TO THE LOWER EDGE. ALSO CORNER BITS ARE ATTACHED TO THE LOWER OUTSIDE CORNERS.

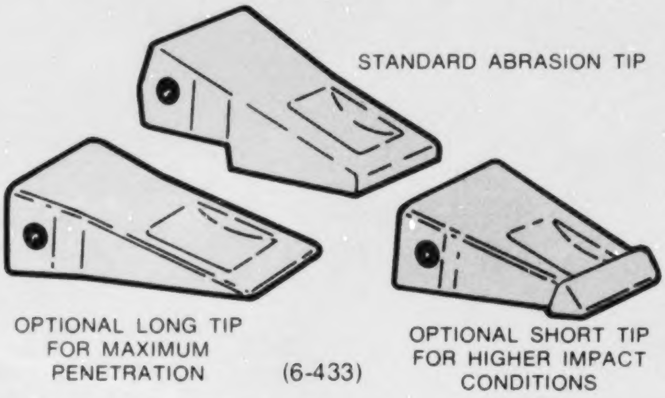
Courtesy of Caterpillar Tractor Co.



BUCKET WITH REPLACEABLE TEETH. ALSO HAVE REPLACEABLE WEAR PLATES UNDERNEATH FRONT EDGE.

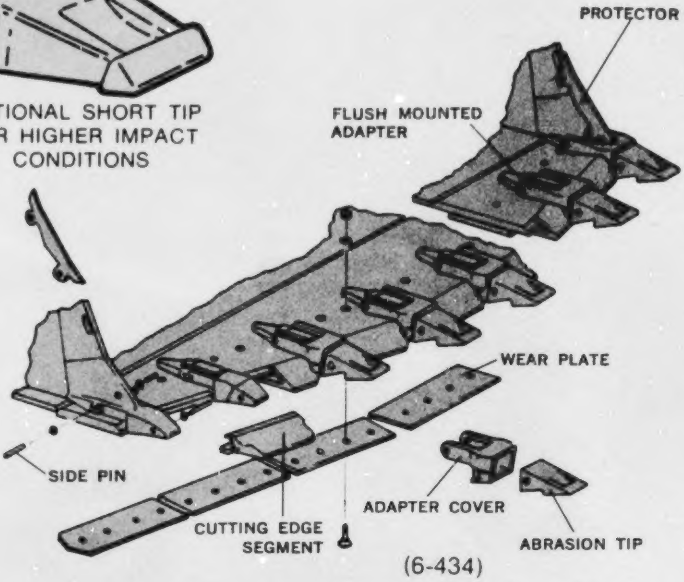
Courtesy of Caterpillar Tractor Co.

(6-432)


STANDARD ABRASION TIP
OPTIONAL LONG TIP FOR MAXIMUM PENETRATION
OPTIONAL SHORT TIP FOR HIGHER IMPACT CONDITIONS

(6-433)

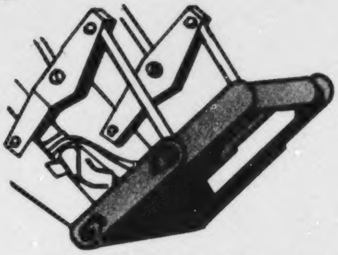
Courtesy of Caterpillar Tractor Co.


PROTECTOR
FLUSH MOUNTED ADAPTER
WEAR PLATE
SIDE PIN
ADAPTER COVER
CUTTING EDGE SEGMENT
ABRASION TIP

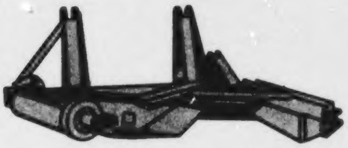
(6-434)

Courtesy of Caterpillar Tractor Co.

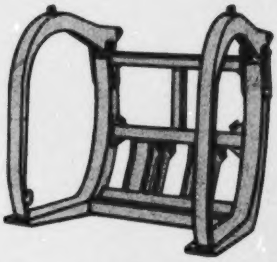
Other wheel loader working attachments are shown in Figure 6-435. Wheel loaders with log forks are very common in the forest industry (Figure 6-436). The forks have replaceable tips allowing the working length of the fork to be restored.



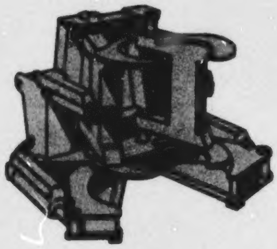
(6-435)
QUICK COUPLERS — PERMIT QUICK SWITCHES OF WORKING ATTACHMENTS



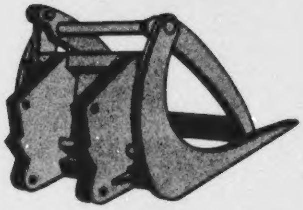
(6-435)
DIRECTIONAL FELLING SHEARS — CUTS TREES UP TO 30 INCHES THICK



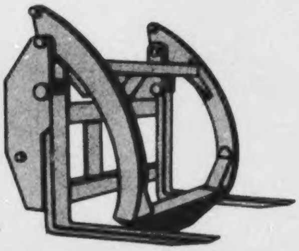
(6-435) LOG FORKS



(6-435)
BUNCHING SHEARS — FALLS AND BUNCHES SMALL TO MEDIUM SIZE TREES



(6-435)
LOW PROFILE FORKS-HANDLE TREE LENGTH PULPWOOD



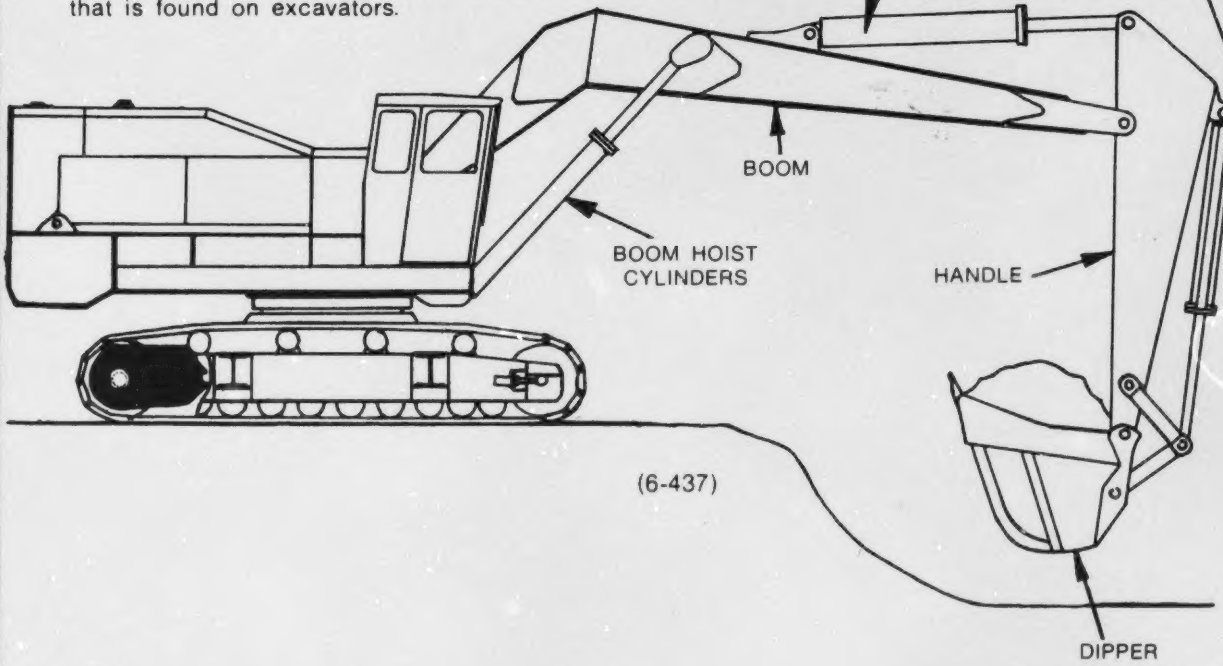
Courtesy of Caterpillar Tractor Co.

(6-435) LUMBER FORKS

(6-436) Courtesy of Caterpillar Tractor Co.

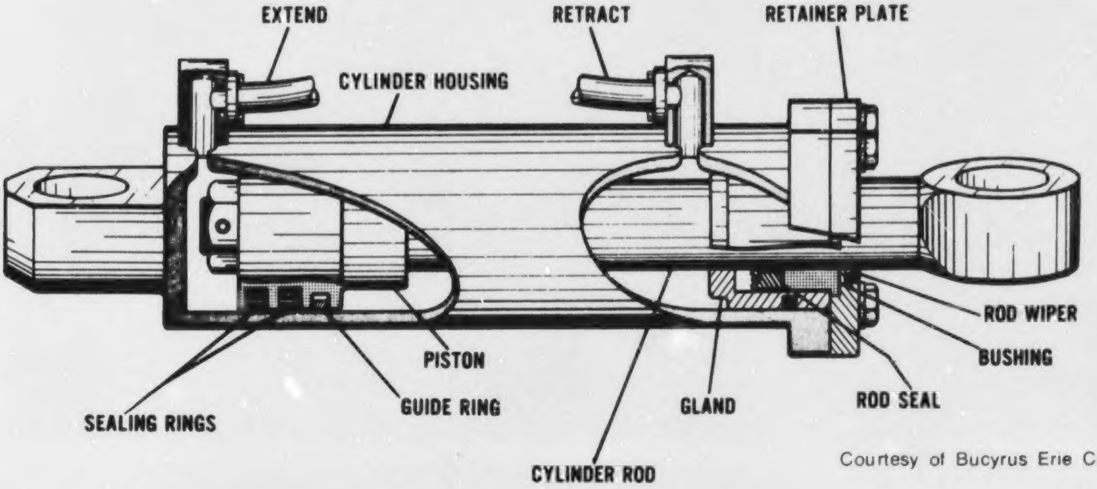
HYDRAULIC EXCAVATOR

Hydraulic excavators are built primarily for digging; a typical one rigged for digging is shown in Figure 6-437. Many shapes and sizes of buckets or dippers are available for excavators. Note in Figure 6-437 the different hydraulic cylinders that are used to operate the dipper. Figure 6-438 shows a more detailed view of the type of hydraulic cylinder that is found on excavators.


DIG CYLINDER
WRIST CYLINDER
BOOM
BOOM HOIST CYLINDERS
HANDLE
DIPPER

(6-437)

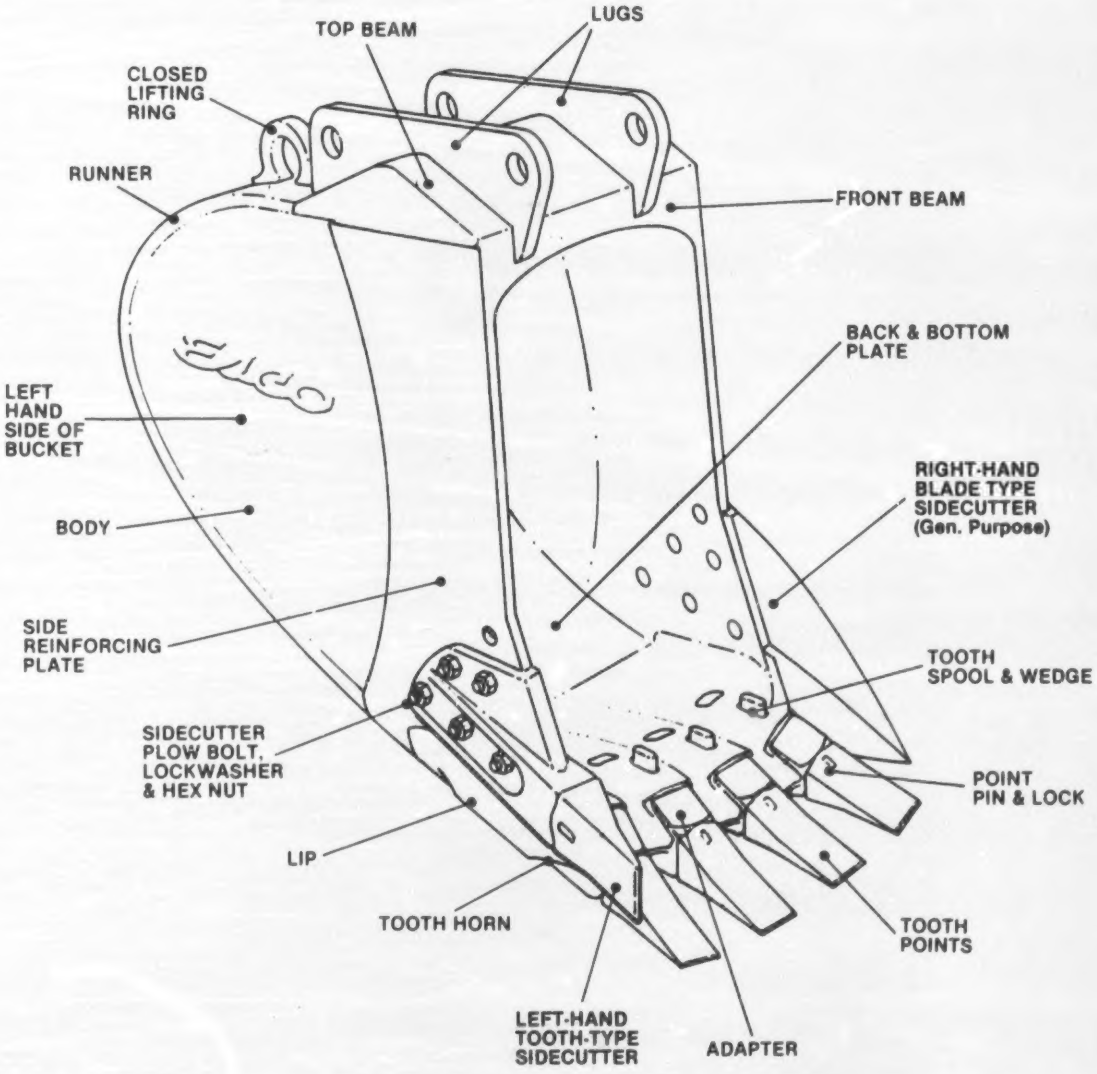
Courtesy of Bucyrus Erie Co.


EXTEND
RETRACT
RETAINER PLATE
CYLINDER HOUSING
ROD WIPER
BUSHING
PISTON
SEALING RINGS
GUIDE RING
GLAND
ROD SEAL
CYLINDER ROD

Courtesy of Bucyrus Erie Co.

(6-438)

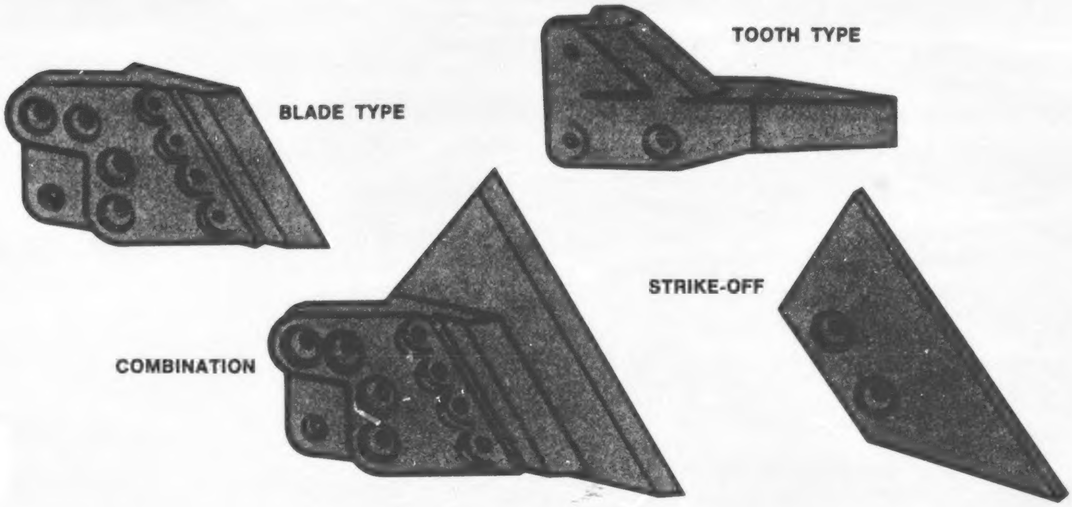
Excavator dippers, like loader buckets and dozer blades, also need protection. In Figure 6-439 note the dipper parts on the digging edge and corners. Two types of sidecutters are shown: the right hand side cutter is a general purpose blade and the left hand side cutter is a tooth. (These and two other types of sidecutters are compared in Figure 6-440.) The bucket teeth consist of an adapter and a tooth point. The adapter is either pinned or welded to the bucket lip, and the tooth point is pinned to the adapter.


LUGS
TOP BEAM
CLOSED LIFTING RING
RUNNER
FRONT BEAM
BACK & BOTTOM PLATE
LEFT HAND SIDE OF BUCKET
RIGHT-HAND BLADE TYPE SIDECUTTER (Gen. Purpose)
BODY
SIDE REINFORCING PLATE
TOOTH SPOOL & WEDGE
SIDECUTTER PLOW BOLT, LOCKWASHER & HEX NUT
POINT PIN & LOCK
LIP
TOOTH HORN
TOOTH POINTS
LEFT-HAND TOOTH-TYPE SIDECUTTER
ADAPTER

LEFT HAND IS LEFT SIDE AS VIEWED BY OPERATOR.

(6-439)

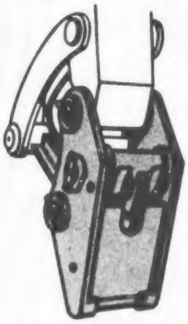
Courtesy of Esco Corporation



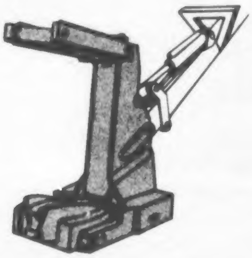
(6-440) SIDECUTTERS

Courtesy of Caterpillar Tractor Co.

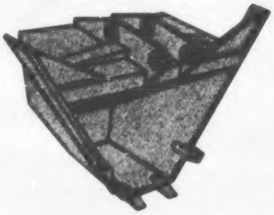
Although hydraulic excavators are used mainly for digging, optional working attachments are available for them. Some are shown in Figure 6-441.



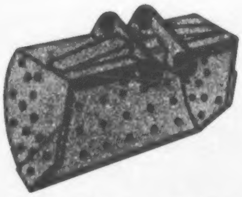
Quick Coupling Devices
For quickly changing
working attachments



Bunching Shears
For falling and
bunching trees

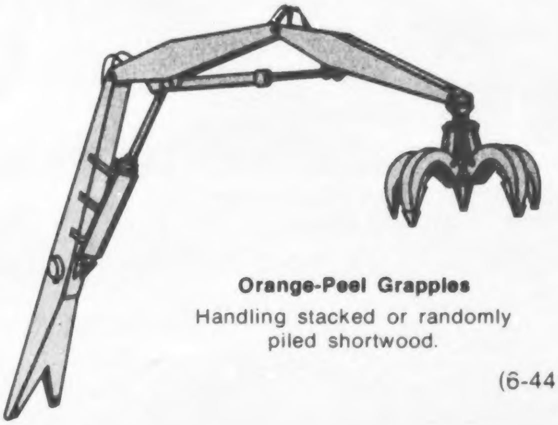


Ditch Forming Bucket

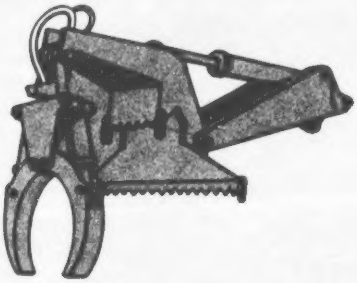


Ditch Cleaning Bucket

(6-441)



Orange-Peel Grapples
Handling stacked or randomly
piled shortwood.



Heel Booms
With main boom, stick,
live heeling rack and grapple
for handling logs

(6-441)

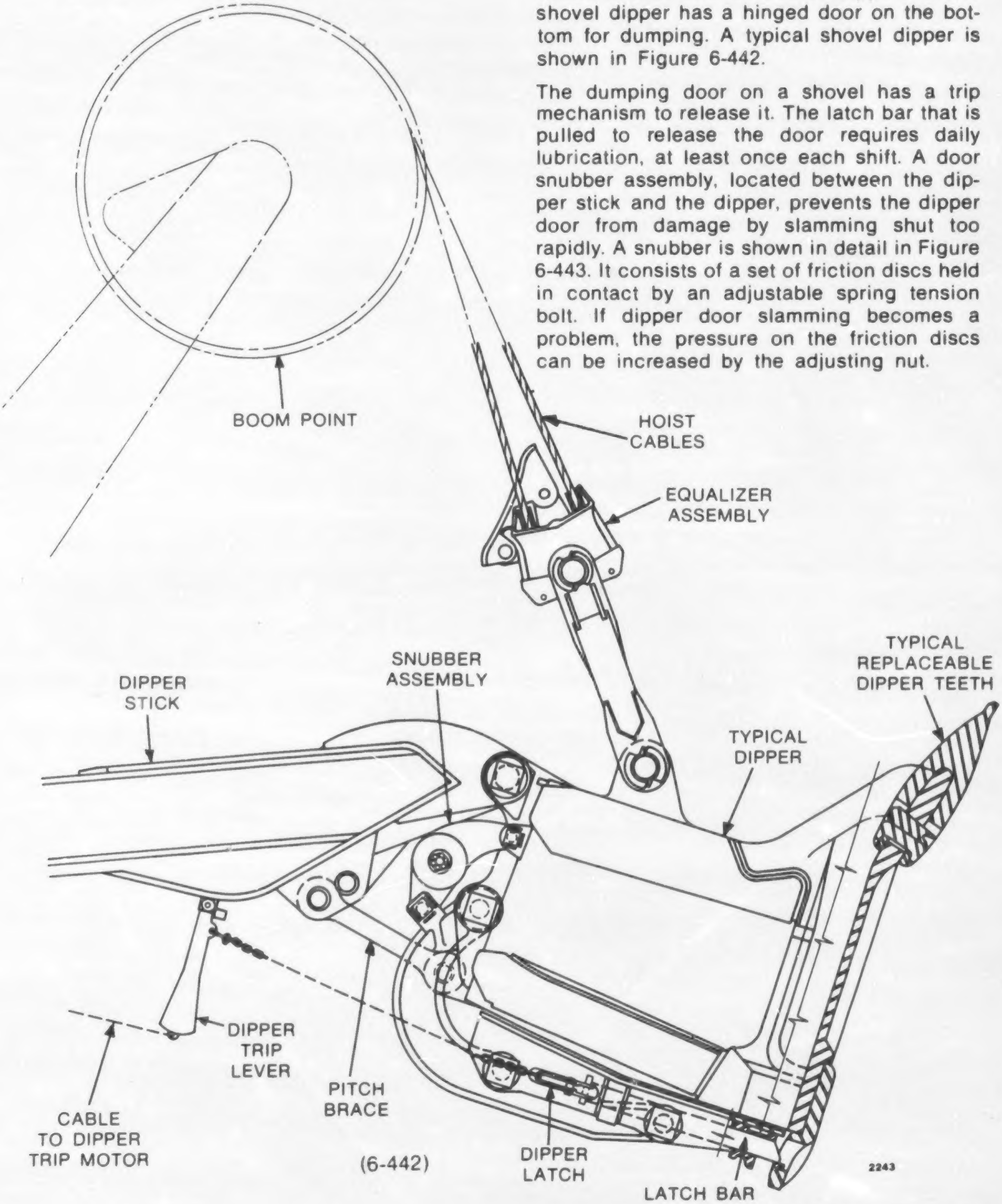
Courtesy of Caterpillar Tractor Co.

CRAWLER SHOVELS

Crawler shovels, as was mentioned earlier (see Figure 9-30), can be converted to cranes, drag lines, clamshells. However, only shovel buckets are discussed here.

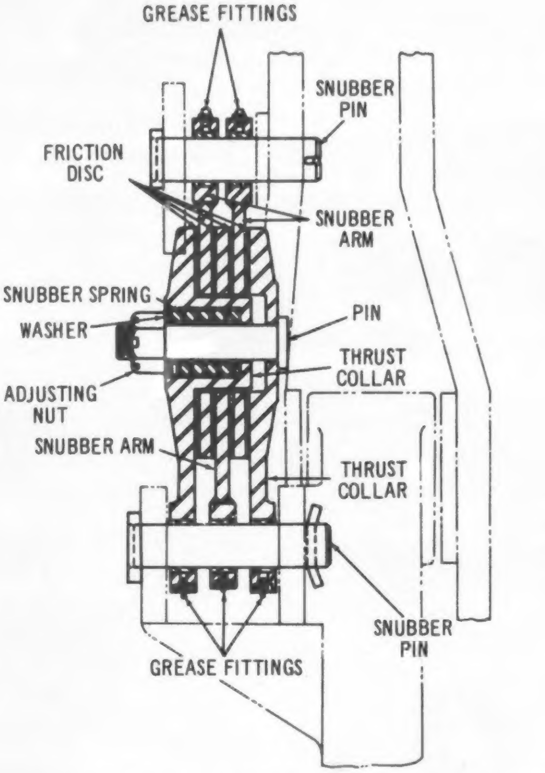
Shovel buckets or dippers are generally much larger than excavator and backhoe dippers. The side of a particular shovel dipper will depend on the machine's size and on the type of material being dug. Another difference between shovel and excavator dippers is the shovel dipper has a hinged door on the bottom for dumping. A typical shovel dipper is shown in Figure 6-442.

The dumping door on a shovel has a trip mechanism to release it. The latch bar that is pulled to release the door requires daily lubrication, at least once each shift. A door snubber assembly, located between the dipper stick and the dipper, prevents the dipper door from damage by slamming shut too rapidly. A snubber is shown in detail in Figure 6-443. It consists of a set of friction discs held in contact by an adjustable spring tension bolt. If dipper door slamming becomes a problem, the pressure on the friction discs can be increased by the adjusting nut.


BOOM POINT
HOIST CABLES
EQUALIZER ASSEMBLY
TYPICAL REPLACEABLE DIPPER TEETH
SNUBBER ASSEMBLY
DIPPER STICK
TYPICAL DIPPER
DIPPER TRIP LEVER
PITCH BRACE
CABLE TO DIPPER TRIP MOTOR
DIPPER LATCH
LATCH BAR
2243

(6-442)

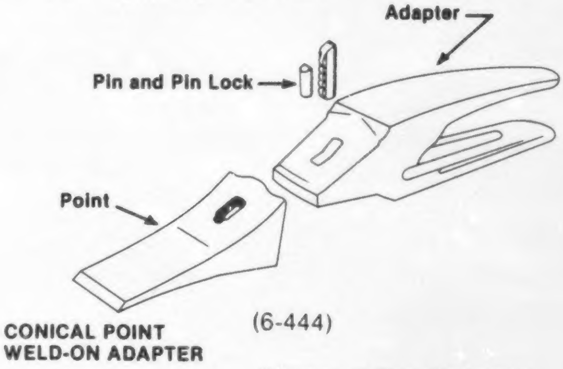
Courtesy of Harnischfeger Corporation P&H


GREASE FITTINGS
SNUBBER PIN
FRICTION DISC
SNUBBER ARM
SNUBBER SPRING
WASHER
PIN
THRUST COLLAR
ADJUSTING NUT
SNUBBER ARM
THRUST COLLAR
SNUBBER PIN
GREASE FITTINGS
2247

(6-443) TYPICAL DIPPER DOOR SNUBBER

Courtesy of Harnischfeger Corporation P&H

Figure 6-444 shows a shovel tooth and adapter. It is important that missing dipper teeth be replaced immediately because operating a dipper without a tooth will destroy the adapter. Replacing an adapter, which is often welded to the dipper, is a much bigger job than replacing the tooth.

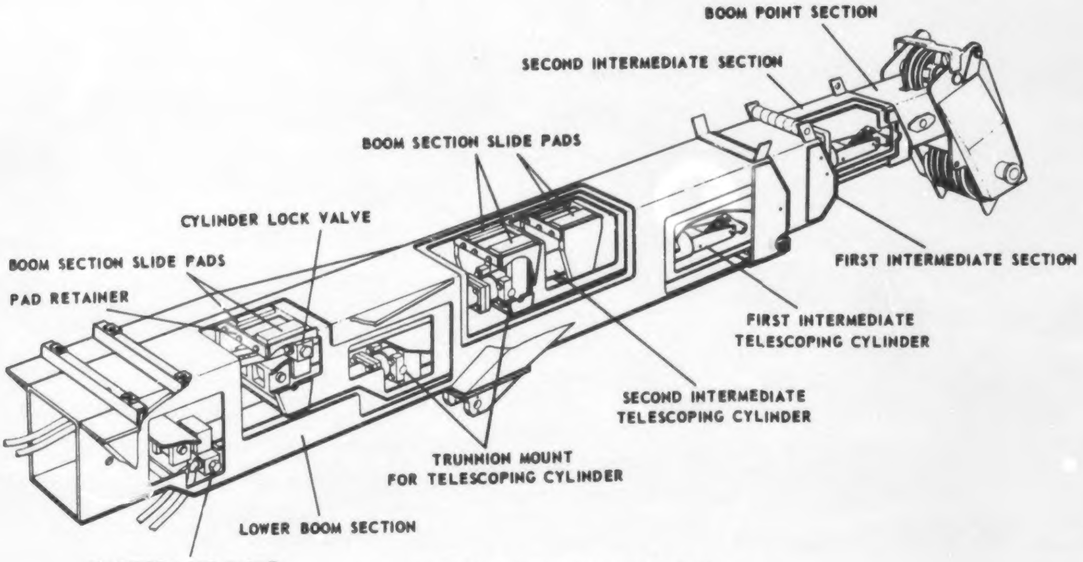

Adapter
Pin and Pin Lock
Point
CONICAL POINT
WELD-ON ADAPTER

(6-444)

Courtesy of Esco Corporation

HYDRAULIC CRANES

Many hydraulic cranes use hydraulic telescopic booms such as the one shown in Figure 6-445. The boom is constructed of several sections (two, three or four), each section having a hydraulic cylinder. Hydraulic lines are all internal. The boom can be expanded or retracted as desired, and in its retracted positions all the sections fit inside of one another like a telescope. The cable from the winch passes over the top of the boom.

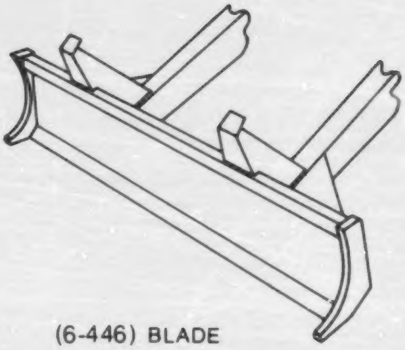

BOOM POINT SECTION
SECOND INTERMEDIATE SECTION
BOOM SECTION SLIDE PADS
CYLINDER LOCK VALVE
BOOM SECTION SLIDE PADS
PAD RETAINER
FIRST INTERMEDIATE SECTION
FIRST INTERMEDIATE TELESCOPING CYLINDER
SECOND INTERMEDIATE TELESCOPING CYLINDER
TRUNNION MOUNT FOR TELESCOPING CYLINDER
LOWER BOOM SECTION
CYLINDER LOCK VALVE

(6-445) TELESCOPIC BOOM

Courtesy of Bucyrus Erie Co.

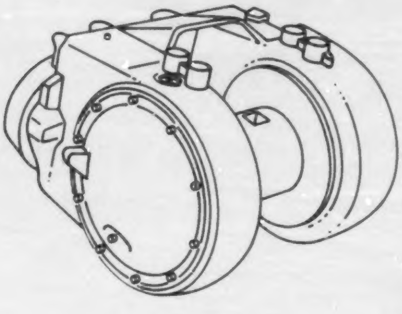
SKIDDERS

Some of the attachments used on a skidder are: a blade for roughing out skid roads, a winch, an arch and fairlead, and a grapple (Figure 6-446 and 6-447). If a skidder has a grapple the arch is generally hydraulically raised and lowered to allow the tongs to pick up the load and lift it for skidding.



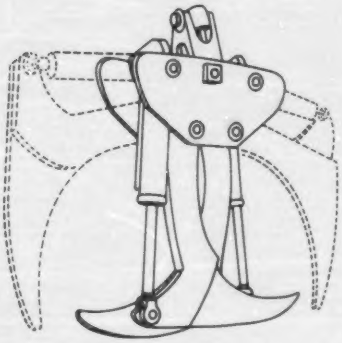
(6-446) BLADE

Courtesy of International Harvester



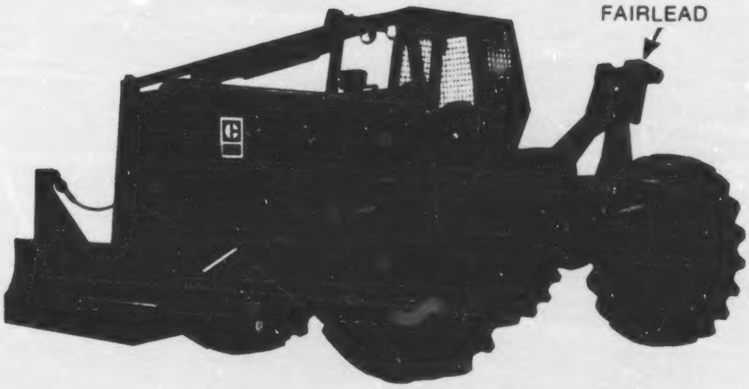
(6-446) WINCH

Courtesy of International Harvester



(6-446) GRAPPLE

Courtesy of International Harvester

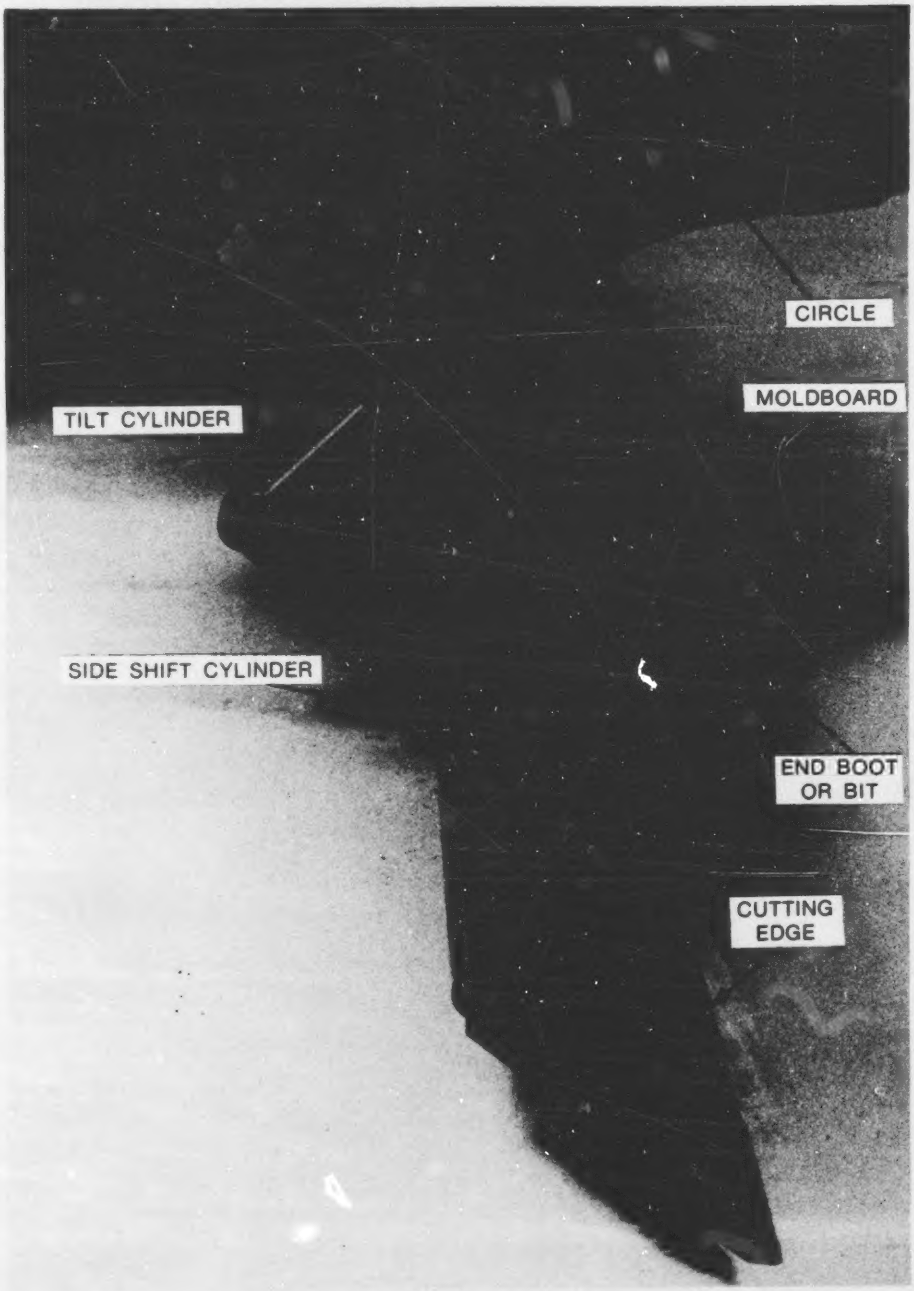


(6-447) SKIDDER

Courtesy of International Harvester

GRADERS

A grader blade (Figure 6-448) is longer and narrower than a dozer blade. The main section of the blade is the curved moldboard. Stiffeners are welded to the back of the moldboard to give it support. Various mounting brackets also add support. For protection, a cutting edge is bolted to the bottom of the blade and end bits are bolted to the outer ends.


CIRCLE
MOLDBOARD
TILT CYLINDER
SIDE SHIFT CYLINDER
END BOOT OR BIT
CUTTING EDGE

(6-448) Courtesy of Champion Road Machinery Limited

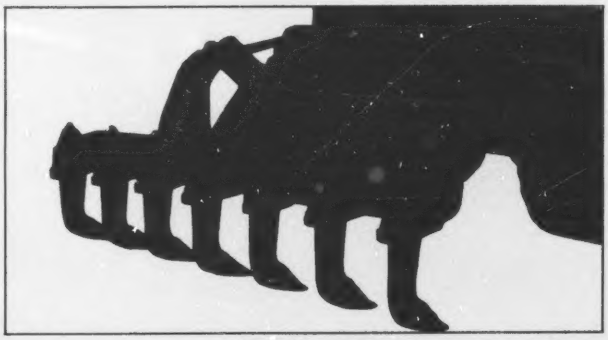
A grader blade has a unique mounting (Figure 6-449). Located between the front and rear wheels under the arch of the main frame, the blade is mounted on a mechanism which permits the blade to move in the following ways:

- swing in an arc on a horizontal plane from a full left to a full right position.
- tilt so that the blade will grade side hills on the left or the right side.
- extend outward from either side of the machine.

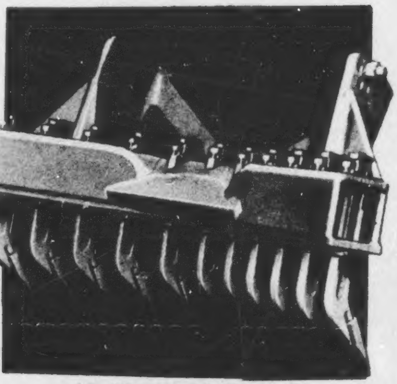
These blade movements are all hydraulically operated on modern machines.

Two common working attachments found on graders are rippers and scarifiers. Rippers (Figure 6-450) are mounted at the rear of the machine. Hydraulic controls raise, lower and tilt the rippers. Scarifiers are also hydraulically operated. Located just ahead of the blade, scarifiers (Figure 6-451) are mounted to the bolster end of the main frame with a pivot pin. They have much shorter teeth than a ripper and are intended mainly to loosen material before it reaches the blade. Teeth for scarifiers and rippers are replaceable.

(6-449)
Courtesy of Champion Road Machinery Limited

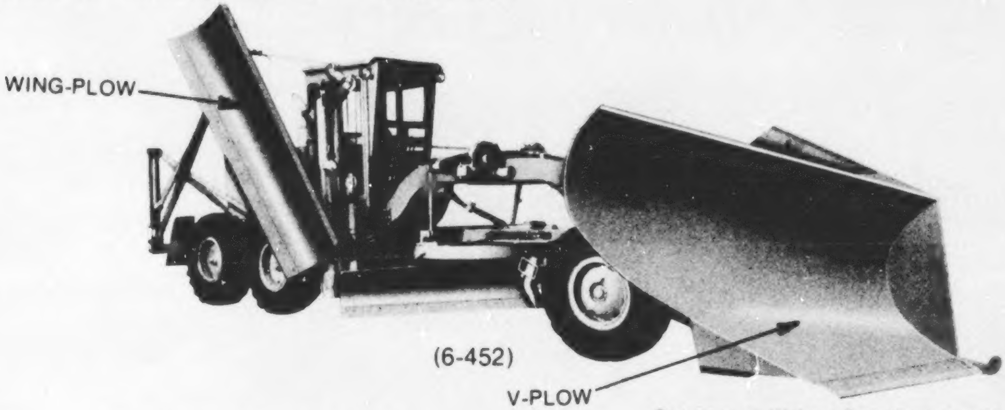


(6-450) RIPPER
Courtesy of Caterpillar Tractor Co.



(6-451) V-SCARIFIER
Courtesy of Wabco Construction and Mining Equipment

Special blades are available for graders. For example, to plow snow a V-plow and a wing plow can be attached to a grader (Figure 6-452). The V-plow in front does the initial clearing, casting the snow left and right. The main blade picks up snow behind the V-plow and sends it to a wing plow which casts the snow off to the right. The V-plow is hydraulically operated whereas the wing plow is usually operated by a combination of cables and hydraulic cylinders. The wing plow can be raised for traveling as it is in Figure 6-452.



(6-452)

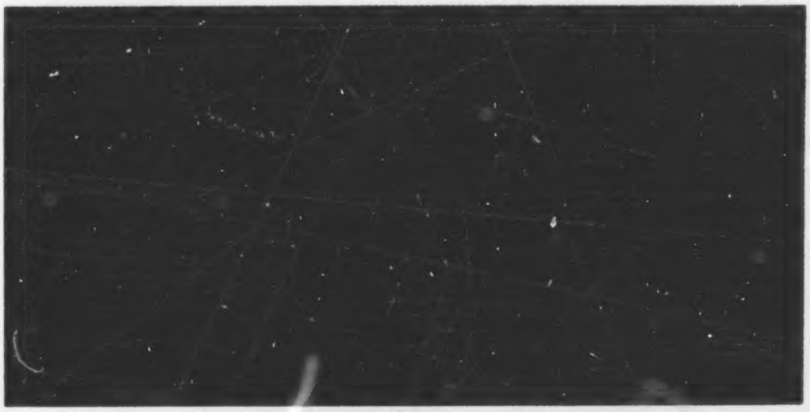
Courtesy of Wabco Construction and Mining Equipment

MACHINE BALANCE AND COUNTERWEIGHTS

Balance of working attachments and loads is an important element in machine design. Take a wheel loader and a crawler loader for example. The wheel loader has the engine mounted towards the rear to counterbalance the weight of the bucket and load. A crawler loader achieves a balance by having the loader frame mounted in the center of the track frame.

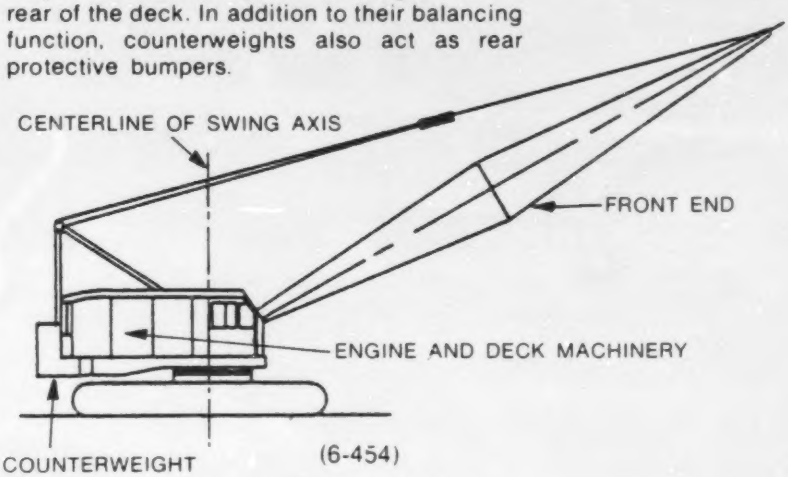
In some situations, however, the weight of the machine cannot adequately counterbalance load weight. If a wheel or crawler loader experiences balancing difficulties when carrying a heavy load, a counterweight can be added to the rear of the main frame or ballast can be added to the wheels. Counterweights can be actual weights or they can be in the form of attachments such as winches or rippers. Figure 6-453 shows a bolt-on counterweight for a loader.

Counterweights are also used for traction. If a machine under heavy load slips, counterweights can be added to the rear of the machine to improve traction. (As discussed in the section on tires, ballast added to tires is also used for this purpose.)



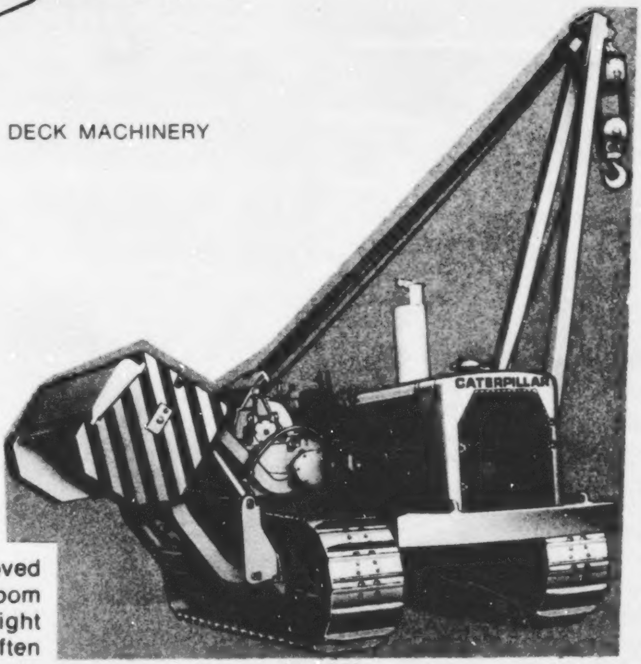
(6-453) Courtesy of Caterpillar Tractor Co.

Shovels or cranes also use counterweights. Although these machines have a balance between the center of the swing axis and the engine and deck machinery (Figure 6-454), they still need heavy counterweights at the rear of the deck. In addition to their balancing function, counterweights also act as rear protective bumpers.



(6-454)

Courtesy of American Hoist and Derrick Co.



(6-455)

Courtesy of Caterpillar Tractor Co.

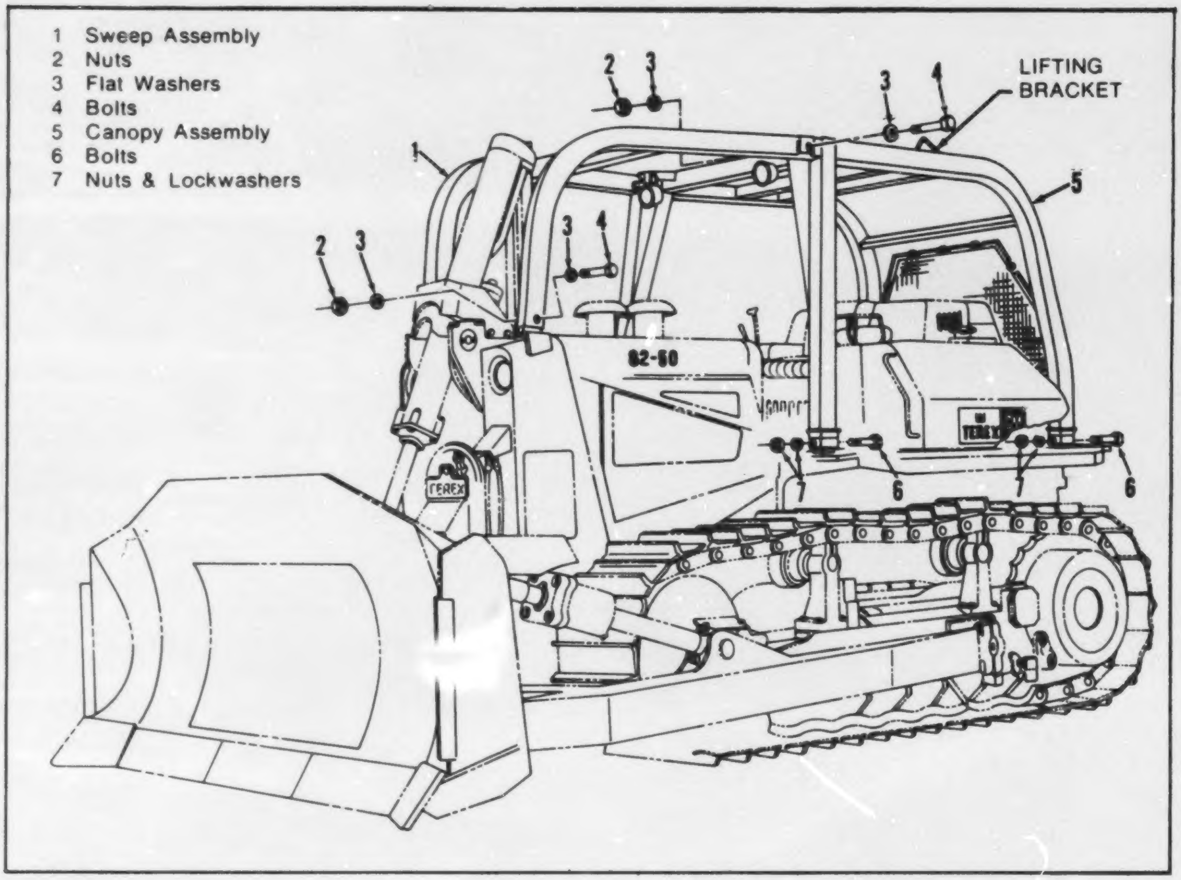
Counterweights may be added or removed when, for example, a longer or shorter boom is put on the machine or the machine's weight is lightened for shipping. Provision is often made on machines for using engine power to lift or lower counterweights. One method is an over the cab cable pulley setup attached to the boom, while another is to use hydraulic cylinders.

Caution: Whenever the front end of a counterweighted machine is removed, the machine is rear heavy and will tip over if not supported.

Crawlers, when equipped with a side boom (Figure 6-455), will have a counterweight on the opposite side. Side booms are common on pipe line work. The counterweight is usually on a hinged mount so that it can be lifted or lowered to change the effective leverage of the weight in proportion to the boom angle and load. The weight is lifted for traveling to make the machine narrower.

CANOPIES

Canopies, or ROPS (Roll Over Protection Structure), are required by law on most heavy duty machines. A typical ROPS mounting for a crawler dozer is shown in Figure 6-456.


1 Sweep Assembly
2 Nuts
3 Flat Washers
4 Bolts
5 Canopy Assembly
6 Bolts
7 Nuts & Lockwashers
LIFTING BRACKET
1
2
3
4
5
6
7
82-60
TEREX

(6-456) ROLLOVER PROTECTIVE STRUCTURE AND MOUNTING HARDWARE

Courtesy of Terex, General Motors Corporation

MAINTENANCE AND SERVICE REPAIR OF WORKING ATTACHMENTS

DAILY ROUTINE MAINTENANCE

Regular checks of working attachments should be part of preventive maintenance programs. The checks can be made during the daily walk around inspection. On buckets, dippers, blades, rippers, scarifiers, make the relevant checks from the list below. Report repairs that need attention.

1. Weld joints — check for cracks or wear.
2. Bucket or dipper — check for:
    - (a) corners worn thin
    - (b) bent or broken reinforcing gussets.
    - (c) bending or bell-mouthing of the bucket.
    - (d) bottom runners that are worn thin.
    - (e) worn or cracked mounting brackets or lugs.
3. Teeth — check for worn or missing teeth. Also check for loose adapters.
4. Bolt-on cutting edges and wear plates — check for worn edges and loose or missing bolts.
5. Sidecutters — check for worn cutters and for loose or missing bolts.
6. Hydraulic cylinders — check for cylinder or hose leaks. Also check that the mounts, pins fittings and hoses are tight.

Examples of service manual preventive maintenance checks for working implements for a Caterpillar wheel loader and grader are shown below.

WHEEL LOADER

When Required	
Bucket Teeth	Inspect condition — replace if necessary
Ripper Teeth	Inspect condition — replace if necessary

GRADER

When Required	
Front Mounted Scarifier Tips	Change when worn close to shank
Blade Circle	Adjust when up and down movement of circle to shoes develops
Cutting Edge and End Bits	Change when worn close to moldboard.
Ripper Tips	Change when worn close to shank.

As mentioned earlier, some companies, especially large ones, have their own P.M. check sheets. Below are two examples of checks on shovel working attachments taken from company P.M. sheets.

LORNEX MINING CORPORATION

NO. 96 FIELD CREW DAILY CHECK LIST

This Sheet To Be Picked Up In Foreman's Office And Returned At Shift End.

Shovels	90-06	90-07	90-08	90-09	90-10	90-11		20-01	20-02	20-03	Remark Column
1. Adapters, Wedges, C-Clamps								X	X	X	
2. Teeth — Replaced or Turned								X	X	X	
Note: Longest Teeth to Operator Side								X	X	X	
3. Wear Caps — Side Cutters								X	X	X	
4. Trip Cable								X	X	X	
5. Latch Lever — Pins and Locks								X	X	X	
6. Latch Bar — Dutchman — Shims								X	X	X	

AFTON MINES

SHIFT PREVENTIVE MAINTENANCE

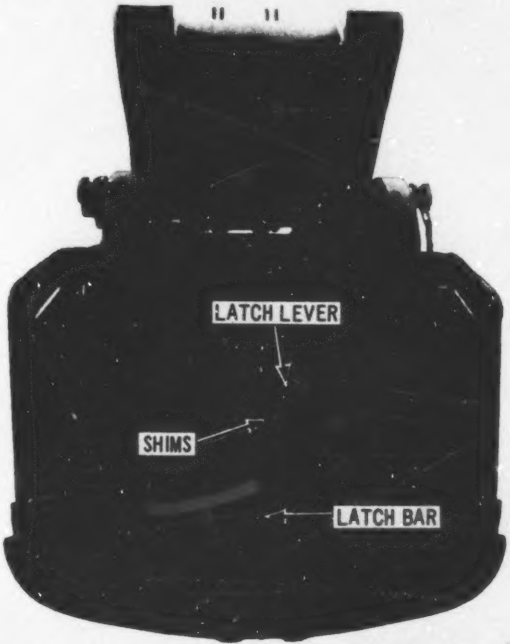
P & H SHOVEL

DATE: ______________________ MECH: ______________________

1900 AL SHOVEL Hr. Reading: 301_____ 302_____ 303_____	301	302	303
1. Dipper Teeth, Caps, Pins			
2. Sidecutters, Keepers			
3. Adapters, C-Clamps, Wedges			
4. Bail Pins, Equalizer Pins, Sheaves, Keepers			
5. Stick/Bucket Pins, Pitch Brace Pins and Keepers			
6. Trip Cable, Chain Latch Assembly			
7. Snubber Brake Assembly			
8. General Wear Condition			

DIPPER DOOR ADJUSTMENTS

Door latches and snubbers on large shovels need adjusting. Latch bars must be adjusted to compensate for wear. As the latch bar length decreases from wear, shims need to be progressively removed from a shim pack located beneath the latch lever (Figure 6-457). Door snubbers, as was mentioned earlier, prevent dipper doors from slamming. If slamming becomes a problem, the pressure on the snubber discs has to be increased by tightening adjusting nuts. When the friction discs can no longer be tightened, they have to be replaced. Note that friction discs should never be lubricated because they are designed to run dry.

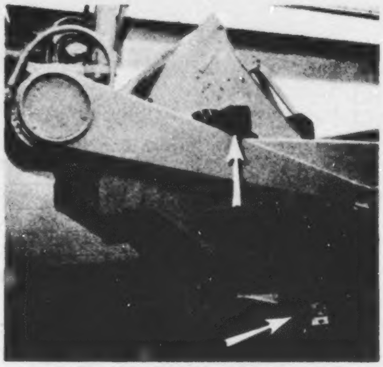


(6-457) DIPPER TRIP LATCH BAR (TYPICAL) 2246

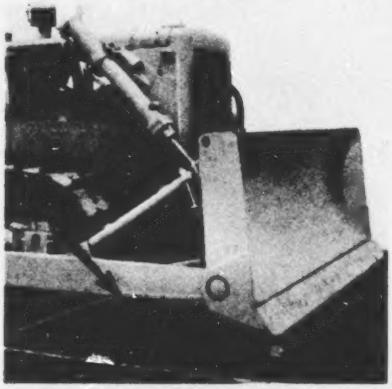
Courtesy of Harnischfeger Corporation P&H

SERVICE REPAIR ON WORKING ATTACHMENTS

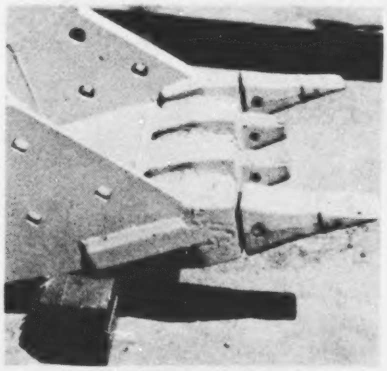
Working attachments are large and heavy and are therefore potentially dangerous. When inspecting or working on implements, they should be lowered to the ground, the engine should be shut down, and the implement controls put in neutral. In the event that an implement has to be lifted to inspect its underside or to replace a cutting edge, corner bit, tooth point, adapter, etc., support the implement with firm blocking (Figure 6-458).



BLOCK BOWL AND APRON BEFORE CHANGING CUTTING EDGE OR ROUTING BITS
(6-458)
Courtesy of Caterpillar Tractor Co.



BLOCK BLADE BEFORE CHANGING CUTTING EDGE OR END BITS
(6-458)
Courtesy of Caterpillar Tractor Co.

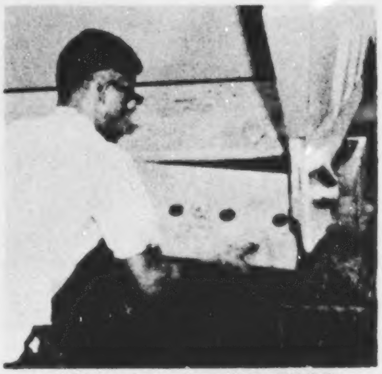


BLOCK BUCKET BEFORE CHANGING BUCKET TEETH OR SIDECUTTERS
(6-458)
Courtesy of Caterpillar Tractor Co.

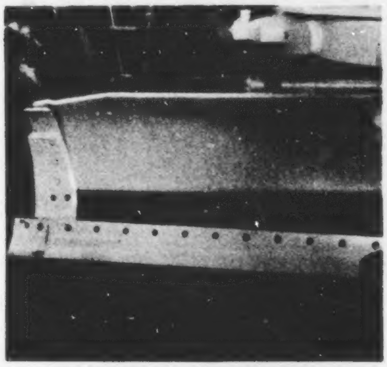
Points When Removing and Installing Cutting Edges, Corner Bits, Tooth Points and Adapters (See service manual for specific procedures).

1. If cutting edge, sidecutter or corner bit bolts are difficult to remove, and in most cases they are, remove them with a cutting torch. Note that cutting edges can sometimes be reversed and reinstalled for additional service life. Similarly, some corner bits can be swapped to opposite sides.

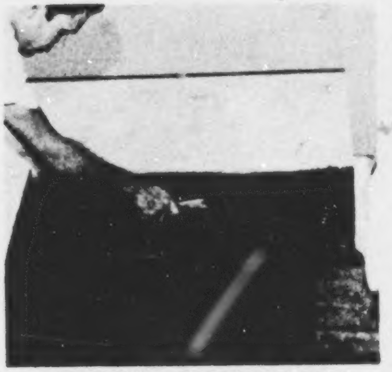
   Figure 6-459 illustrates removing cutting edges, sidecutters, and end bits. Figure 6-460 shows replaceable cutting edges and corner bits on a dozer blade.



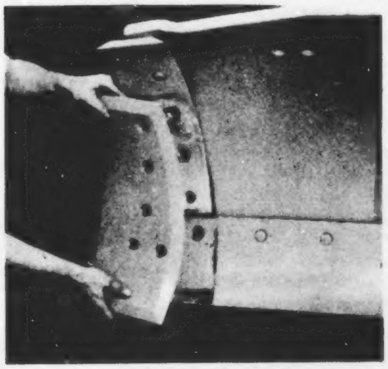
SCRAPER CUTTING EDGE
(6-459)
Courtesy of Caterpillar Tractor Co.



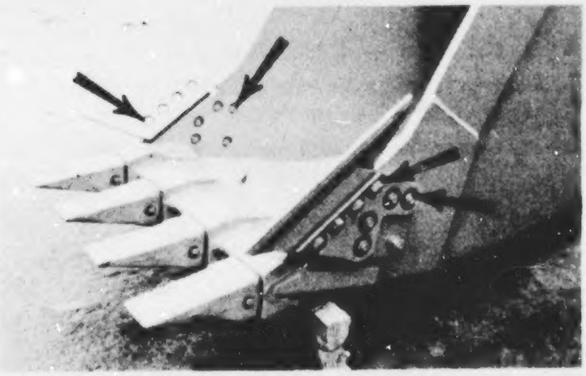
GRADER CUTTING EDGE
(6-459)
Courtesy of Caterpillar Tractor Co.



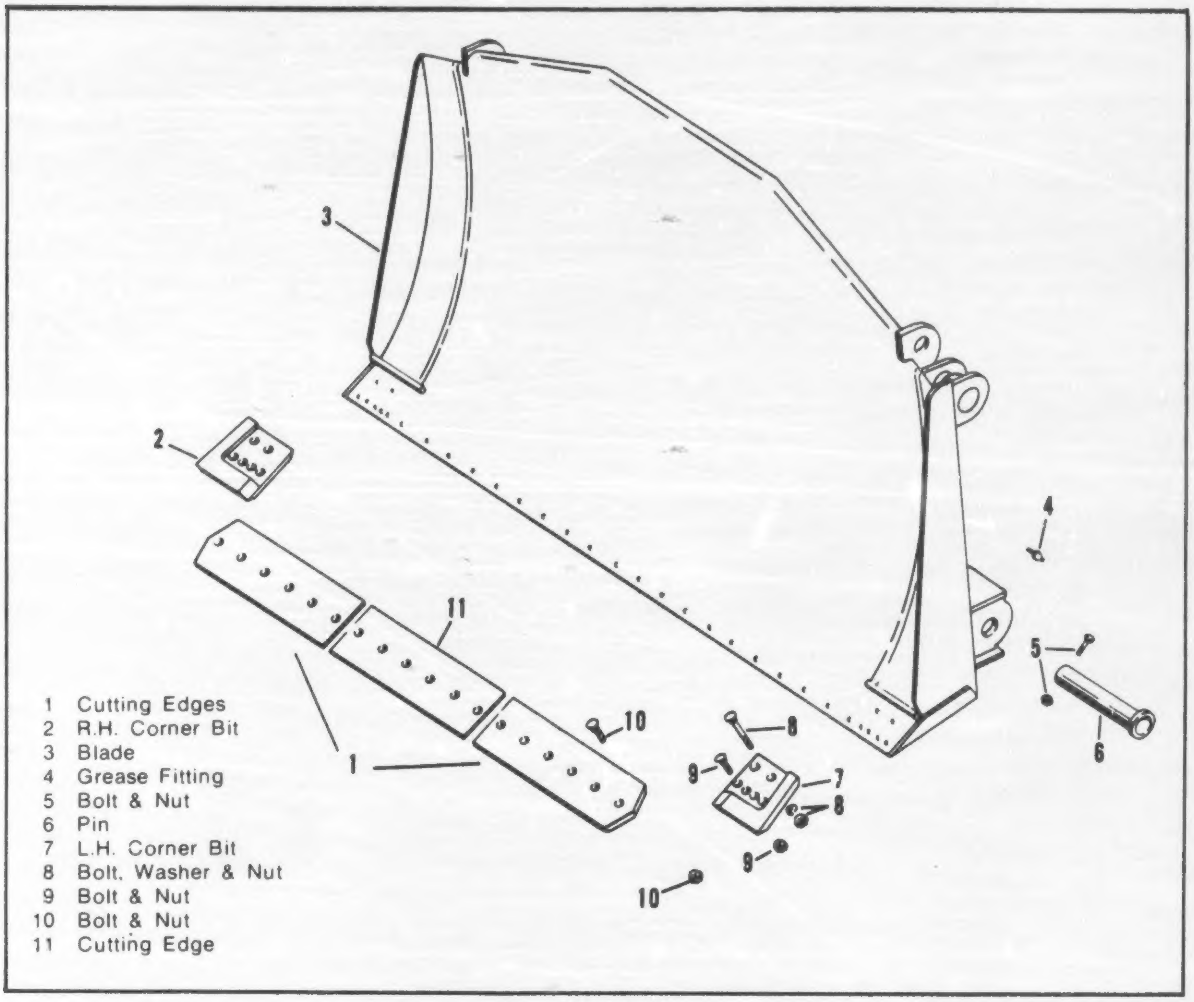
CLEANING CUTTING EDGE CONTACT SURFACE
(6-459)
Courtesy of Caterpillar Tractor Co.



GRADER END BITS
(6-459)
Courtesy of Caterpillar Tractor Co.



SIDECUTTERS AND MOUNTING BOLTS
(6-459)
Courtesy of Caterpillar Tractor Co.



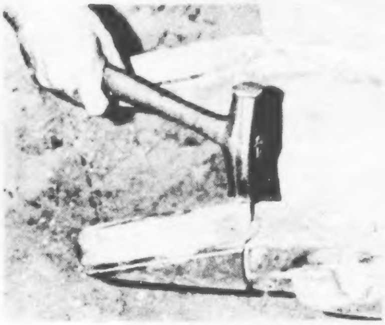
1 Cutting Edges
2 R.H. Corner Bit
3 Blade
4 Grease Fitting
5 Bolt & Nut
6 Pin
7 L.H. Corner Bit
8 Bolt, Washer & Nut
9 Bolt & Nut
10 Bolt & Nut
11 Cutting Edge

(6-460) Courtesy of Terex, General Motors

2. Clean the areas where new parts are to be installed and scrape paint from the contact surface of new cutting edges, sidecutters, and corner bits. Carefully check the bucket, dipper or blade for cracks near the bolt-on areas. Use new bolts to install the parts and torque them to specification. To ensure the bolts are seated properly, strike the bolt heads with a hammer while tightening them. Recheck bolt torque after one or two shifts.

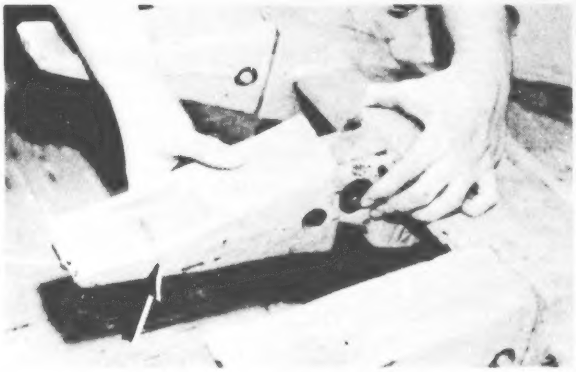
3. To remove bucket teeth and ripper shrouds and tips, a pin must be driven out (Figure 6-461). Some adapters for teeth are also held by pins. Before attempting to remove a pin, clean around the pin area with a wire brush. When installing new parts that are held by pins, always use new pins and new rubber bushings (if equipped). Note when installing teeth that many of them have a digger side and a running side, and the desired side has to be placed face down. Figure 6-461, 6-462, and 6-463 show the installation and removal of teeth and tips.

Warning: To avoid eye injuries, wear safety glasses when striking pins. Also, take precautions that the pin does not fly out and hit someone nearby.

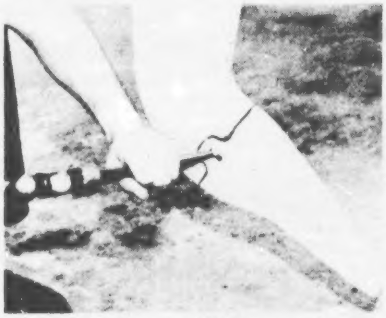


SLIDE TIP OVER ADAPTER TO
ALIGN PIN HOLES AND
INSTALL PIN

(6-461) INSTALLING NEW TEETH
Courtesy of Caterpillar Tractor Co.



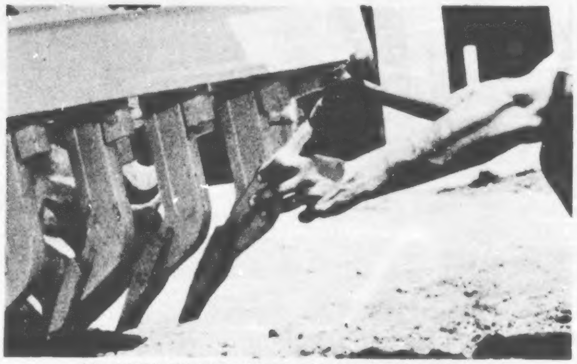
INSTALL NEW TOOTH
OVER WASHER



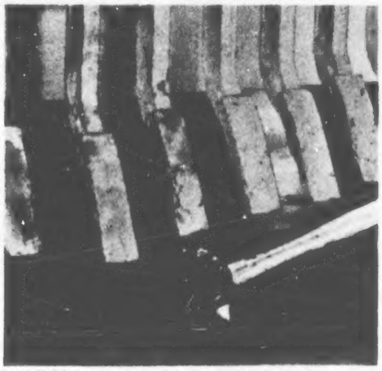
RIPPER
Courtesy of Caterpillar Tractor Co.

(6-461) DRIVING OUT PINS

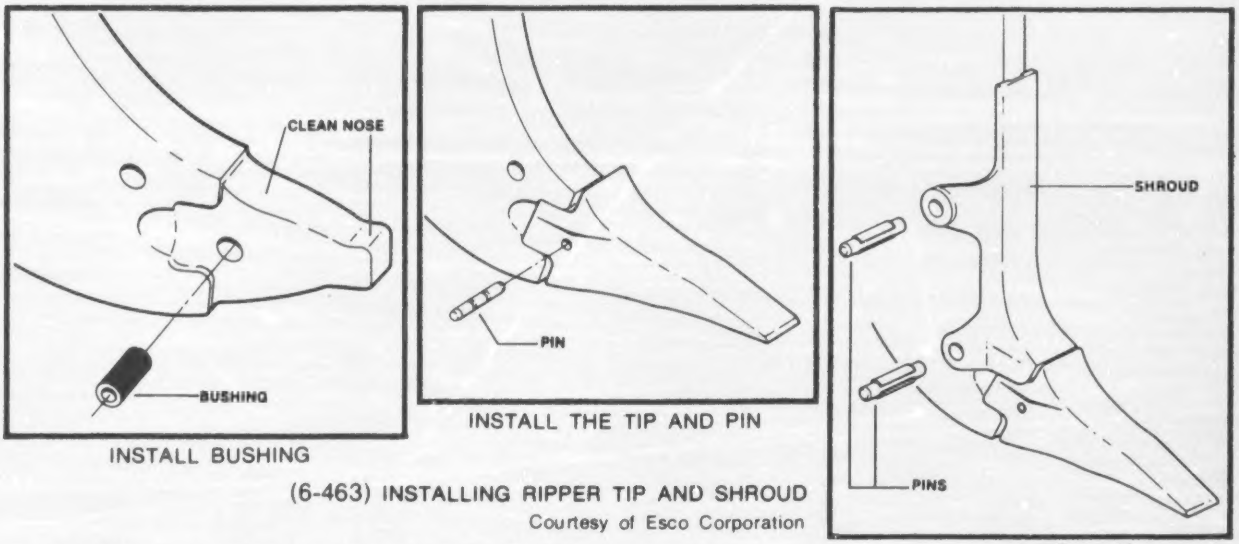
BUCKET
Courtesy of Caterpillar Tractor Co.



(6-462) REMOVING SCARIFIER TIP



(6-462) INSTALLING SCARIFIER TIP
Courtesy of Caterpillar Tractor Co.


CLEAN NOSE
BUSHING
PIN
SHROUD
PINS

INSTALL BUSHING

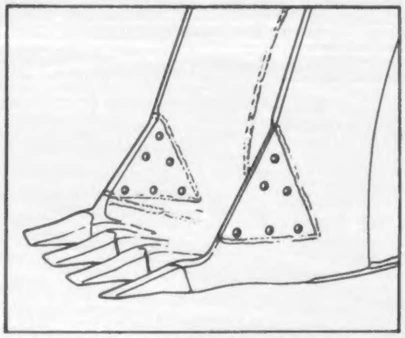
INSTALL THE TIP AND PIN

INSTALL SHROUD

(6-463) INSTALLING RIPPER TIP AND SHROUD

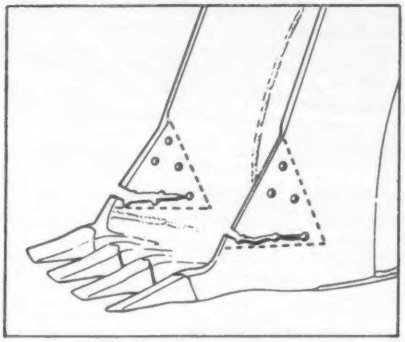
Courtesy of Esco Corporation

4. Welding repairs can be used to repair the non-replaceable, or at least the not readily replaceable, parts of working attachments. The two examples of welding repairs to a dipper shown in Figures 6-464 and 6-465, would generally be done by a welding shop.

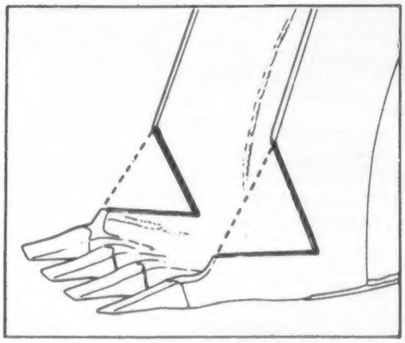


3. WELD IN NEW PLATE WITH SIDECUTTER BOLT HOLES

(6-464) REPAIRING DIPPER CORNERS

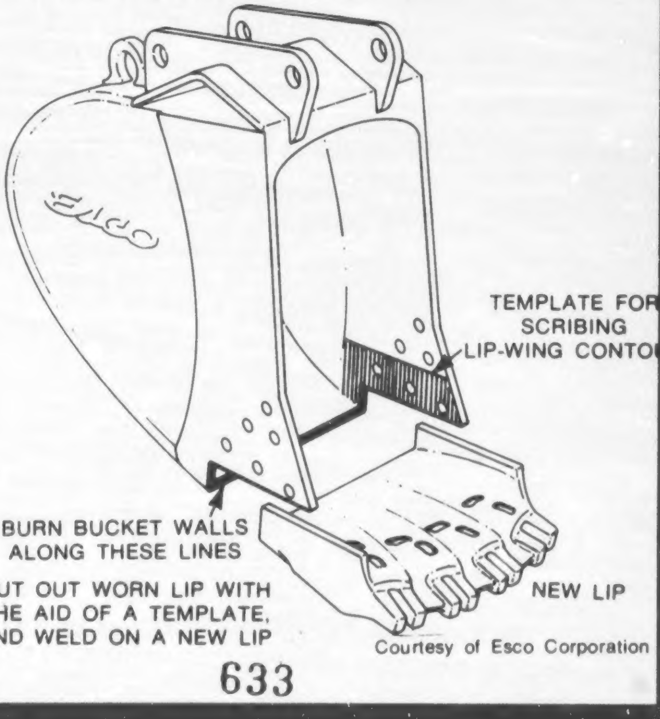


1. CRACKED OR WORN OUT AREA NEEDS REPAIR



2. CUT OUT ENTIRE SECTION

Courtesy of Esco Corporation


ESCO
TEMPLATE FO
SCRIBING
LIP-WING CONTO
BURN BUCKET WALLS
ALONG THESE LINES
NEW LIP

(6-465) CUT OUT WORN LIP WITH THE AID OF A TEMPLATE, AND WELD ON A NEW LIP

Courtesy of Esco Corporation

QUESTIONS — WORKING ATTACHMENTS

1. When selecting a dozer blade, what are the two main factors to consider?
2. True or False? Hardened steel cutting edges are welded to the bottom edge of a dozer blade to extend blade life.
3. What function does a ripper perform?
4. How does a loader bucket mounting differ from a dozer blade mounting?
5. What are the three common types of protection available for loader buckets?
6. What job would a grapple be used for on a wheel loader?
7. What is the function of a quick coupling device for a hydraulic excavator?
8. The devices used to protect the front corners of an excavator dipper and to aid in digging are called:
    - (a) side lips
    - (b) wear plates
    - (c) tooth points
    - (d) sidecutters
9. How do shovel dippers differ from excavator dippers?
10. What device is used to prevent door slamming on a shovel dipper?
    - (a) snuffer
    - (b) snubber
    - (c) door stopper
    - (d) tension bolt
11. A tooth point used on a shovel dipper is held by a:
    - (a) weld
    - (b) bolt
    - (c) friction bit
    - (d) drift pin
12. True or False? Adapters for shovel dipper teeth are virtually indestructable.
13. A scarifier on a grader is mounted:
    - (a) at the rear of the machine
    - (b) just behind the grader blade
    - (c) just ahead of the grade blade
    - (d) ahead of the front wheels
14. Give two reasons for adding counterweights to a machine.
15. Counterweights can be actual weights or they can be in the form of ________.
16. What methods do shovels and cranes often have for raising and lowering counterweights?
17. What safety procedure must be taken if the front end of a counterweighted machine is removed?
18. Part of preventive maintenance programs is to make regular checks on working attachments:
    - (a) daily
    - (b) weekly
    - (c) monthly
    - (d) twice yearly
19. Referring to the service manual information given in this section for a Caterpillar grader, when is it recommended that scarifier tips be replaced?
20. What two maintenance adjustments are required on large shovel dippers?
    - (a) dipper door hinge pins and trip lever
    - (b) dipper door latch bar and trip lever
    - (c) dipper door latch bar and snubber
    - (d) dipper door hinge pins and tooth points
21. When working on or inspecting working attachments, what safety precaution must be taken?
22. True or False? New parts such as cutting edges and corner bits should have the paint scraped off their contact surfaces to prevent the parts from working loose in service.
23. How do you remove bolts on working attachments that are hard to get off with a wrench?
24. Many bucket teeth are two-sided, having a ________ side and a ____________ side.

ANSWERS — WORKING ATTACHMENTS

1. The size of the dozer's engine. The type of work the dozer will mainly be doing.
2. False. The edges are bolted.
3. A ripper loosens material for easier dozing.
4. Loader bucket lift arms are attached to a tower that is part of, or attached to, the tractor's main frame. A dozer's blade is attached to trunnions outside the tracks frames.
5. — cutting edges
   — wear strips
   — teeth
6. Log loading.
7. For changing working implements quickly.
8. (d) sidecutters.
9. The shovel dipper has a hinged door at the bottom for dumping, while excavator dippers are solid and roll to dump.
10. (b) snubber
11. (d) drift pin
12. False. Running a bucket with an exposed adapter will destroy the adapter.
13. (c) just ahead of the grader blade.
14. — counterbalance load weight
    — improve traction
    — give rear bumper protection
15. . . . attachments.
16. — a cable and pully system
    — hydraulic cylinders
17. Support the rear of the machine.
18. (a) daily.
19. When the tips are worn close to the shank.
20. (c) dipper door latch bar and snubber.
21. — lower all attachments onto good sound blocking
    — shut engine down
    — put controls in neutral
22. True.
23. Cut them off with a cutting torch.
24. . . . . digger . . . . . running. . .

TASKS — WORKING ATTACHMENT

ROUTINE MAINTENCE CHECK

1. Inspect the working attachments on one of the following machines:

Dozer
Loader
Backhoe
Excavator
Scraper
Grader
Shovel

Look for worn or damaged areas, cracks, welds, bends and twists. Make a service report and present it to your supervisor. The report should include: areas to be repaired and parts to be replaced such as bucket teeth (and pins and bushings), ripper or scarifier tips, cutting edges, wear plates, corner or end bits.

SERVICE REPAIR

1. On one of the machines listed above, raise the working attachment, position blocks, lower the attachment onto the blocks and check to see that it is secure. Using the correct tools and equipment, remove and install parts ordered in task one. When the new parts have been installed, raise the working implement remove the blocks, and lower the implement to a safe position.